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Welsbach / General Gas Mantle Contamination Superfund Site Camden and Gloucester City, New Jersey

Final Feasibility Study OU 2: Armstrong Building

For: U.S. Army Corps of Engineers

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Kansas City District

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OU 2: Armstrong Building
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Acronyms Used in the Report

%	Percent
ACM	Asbestos-Containing Materials
ANL	Argonne National Laboratory
AOC	Administrative Order on Consent
ARAR	Applicable or Relevant and Appropriate Requirement
BPRG	Preliminary Remediation Goals for Radionuclides in Buildings
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cy	Cubic Yards
dpm/ cm^2	Disintegrations per Minute per Square Centimeter
dpm/100 cm^2	Disintegrations per Minute per 100 Square Centimeters
EDE	Effective Dose Equivalent
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
FSS	Final Status Survey
ft^2	Square Feet
HEAST	Health Effects Assessment Summary Tables
HEPA	High Efficiency Particulate Air
Holt Cargo	Holt Cargo Systems
HotSpot	HotSpot Health Physics Code
HVAC	Heating, Ventilation, and Air Conditioning
IC	Institutional Control
IDW	Investigation-Derived Waste
IEM	Integrated Environmental Management, Inc.
LBP	Lead-Based Paint
LCP	Lead-Containing Paint
LLC	Limited Liability Company
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
mg/kg	Milligrams/Kilogram
MM	Million
mrem/year	Millirem Per Year
NARAC	National Atmospheric Release Advisory Center
NCP	National Oil and Hazardous Substances Contingency Plan
NESHAP	National Emission Standards for Hazardous Air Pollutants

NJ	New Jersey
NJDEP	New Jersey Department of Environmental Protection
O&M	Operation and Maintenance
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
pCi/L	Picocuries Per Liter
ppm	Parts per Million
PPE	Personal Protective Equipment
PRG	Preliminary Remediation Goal
Ra-226	Radium 226
RA	Risk Assessment
RACER	Remedial Action Cost Engineering and Requirements
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
Redox	Oxidation/Reduction
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
Rn-220	Radon 220 (thoron)
Rn-222	Radon 222 (radon)
Rn/Tn	Radon/Thoron
ROD	Record of Decision
Site	Welsbach/General Gas Mantle Contamination Superfund Site
TC	Toxicity Characteristic
TCLP	Toxicity Characteristic Leaching Procedure
Th-232	Thorium 232
TBC	To Be Considered
UQSM	Unimportant Quantities of Source Material
USACE	U.S Army Corps of Engineers
USDOE	U.S. Department of Energy
USDOT	U.S. Department of Transportation
USNRC	U.S. Nuclear Regulatory Commission

Executive Summary

Introduction/Background

This report presents the results of the Feasibility Study (FS) prepared by ARCADIS/Malcolm Pirnie for Operable Unit (OU) 2 of the Welsbach/General Gas Mantle Contamination Superfund Site (Site). This FS was prepared for the U.S. Environmental Protection Agency (EPA) Region 2, under U.S Army Corps of Engineers (USACE) Kansas City District Contract No. W912DQ-08-D-0017, Delivery Order 0018.

Between the 1890s and 1940s, Welsbach manufactured gas mantles at its facility in Gloucester City, New Jersey (NJ). The Armstrong Building, OU2, is the last building remaining from Welsbach's operations. This three-story structure is located on the northwestern corner of Ellis and Essex Streets, Gloucester City, NJ on an active port, warehouse and logistics facility on the Delaware River. The Walt Whitman Bridge is located just north of the building, residential areas are located immediately east and southeast, and the Delaware River is located approximately 1,000 feet to the west.

In May 1997, in an effort to expedite EPA's cleanup, Holt Cargo, the former owner of the Armstrong Building property, voluntarily entered into an Administrative Order on Consent (AOC) with EPA to conduct a Remedial Investigation/FS (RI/FS) for the Armstrong Building. Holt Cargo contracted with Integrated Environmental Management, Inc. (IEM) to conduct this work; the investigation was conducted in 1998. Under the AOC, Holt Cargo submitted the following reports to EPA:

- *Remedial Investigation Report for the Armstrong Building*, July 1998 (IEM, 1998)
- *Comparative Analysis of Remedial Alternatives*, May 1999 (IEM, 1999)
- *Baseline Risk Assessment for the Armstrong* Building, January 2000 (IEM, 2000a)
- *Feasibility Study for the Armstrong Building*, January 2000 (IEM, 2000b)

Based on a review of IEM's RI, EPA identified several potential data gaps, including a number of wall surfaces which were covered by insulation and other materials that blocked IEM's investigation of these surfaces. Therefore, in 2010 ARCADIS/Malcolm Pirnie conducted a supplementary investigation at the Armstrong Building to collect a limited amount of additional data to close the data gaps identified in IEM's RI.

Remedial Investigation Results

Radioactive contamination was not found on the 1st floor of the Armstrong Building. On the second floor, radioactive levels above the field investigation and/or screening levels were found in five of nine rooms on that level (Rooms 9, 10, 11, 13, and Area B). On the third floor, radioactive levels above the field investigation and/or screening levels were found in all nine rooms (Rooms 15, 16, 17, 18, 19, 20, 21, 22, and Area A). Radionuclides of concern include thorium-232 and radium-226.

Summary of Site Risks

Under Holt Cargo's AOC with EPA, IEM developed a Baseline RA in January 2000. Since the IEM Baseline RA is over ten years old, and there have been updates/improvements in modeling computer codes over the past decade, and since additional exposure scenarios and human receptors have been identified, ARCADIS/Malcolm Pirnie develop a new Baseline RA. Data from both IEM's RI and ARCADIS/Malcolm Pirnie's supplementary RI were used to characterize the nature and extent of radioactive contamination in the Armstrong Building for the purpose of the ARCADIS/Malcolm Pirnie Baseline RA. The Baseline RA concluded that incremental lifetime cancer risks within or above the upper bound of the risk range were calculated for Rooms 9, 10, 11, 13, 15, 17, 21, 22, and Area A.

Feasibility Study Approach

The objectives of this FS are to:

- Develop remedial action objectives (RAOs) based on the findings of the RI and Baseline Risk Assessment (RA), as well as review potential Applicable or Relevant and Appropriate Requirements (ARARs).
- Develop a site-specific Preliminary Remediation Goal (PRG) for the remedial action.
- Identify and screen remedial technologies.
- Develop and screen remedial alternatives.
- Conduct a detailed analysis of remedial alternatives including FS cost estimates.

The RAOs developed for the Armstrong Building to protect human health and the environment include:

- Preventing exposure from radiological contamination on building surfaces.
- Preventing future release of radioactive contamination from the Armstrong Building to the environment.

The Site-specific PRG developed for Armstrong Building, was based on both IEM's and ARCADIS/Malcolm Pirnie's RI results, as well as ARCADIS/Malcolm Pirnie's Baseline RA and is based on risk-based surface activities. The PRG was derived by iteratively re-running RESRAD-BUILD and modifying radionuclide-normalized source surface activities for those rooms/areas evaluated in the Building Reuse/Residential scenario of the Baseline RA (ARCADIS/Malcolm Pirnie, 2011) that had cancer risks within or above the upper bound of the risk range (*i.e.*, Rooms 9, 10, 11, 13, 15, 17, 21, and Area A). Based on this, a PRG of 500 disintegrations per minute per 100 square centimeters, not including background, was calculated for all radionuclides of concern.

Alternative Development

Following the technology screening and screening evaluation, three alternatives were retained for a detailed evaluation of the nine criteria contained in the NCP. The three alternatives include Alternative 1, No Action, Alternative 2, Complete Decontamination and Off-Site Disposal, and Alternative 3, Demolition and Off-Site Disposal.

1 INTRODUCTION

ARCADIS/Malcolm Pirnie prepared this Feasibility Study (FS) for Operable Unit (OU) 2 of the Welsbach/General Gas Mantle Contamination Superfund Site (Site), for the U.S. Environmental Protection Agency (EPA) Region 2, under U.S Army Corps of Engineers (USACE) Kansas City District Contract No. W912DQ-08-D-0017, Delivery Order 0018. The Site covers several square miles in Camden and Gloucester City, Camden County, New Jersey (NJ); OU2, the Armstrong Building, is located on an active cargo terminal in Gloucester City, NJ. A more detailed summary of the Site history and previous Armstrong Building investigations is contained in the *Supplementary Remedial Investigation (RI) Report*, prepared by ARCADIS/Malcolm Pirnie (ARCADIS/Malcolm Pirnie, 2011).

1.1 PURPOSE

ARCADIS/Malcolm Pirnie prepared this FS for the Armstrong Building consistent with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986 (CERCLA), as well as the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988 Office of Solid Waste and Emergency Response (OSWER) Directive No. 9355.3-01) was also followed. The objectives of this FS are to:

- Develop remedial action objectives (RAOs) based on the findings of the RI and Baseline Risk Assessment (RA), as well as review potential Applicable or Relevant and Appropriate Requirements (ARARs).
- Develop a site-specific Preliminary Remediation Goal (PRG) for the remedial action.
- Identify and screen remedial technologies.
- Develop and screen remedial alternatives.
- Conduct a detailed analysis of remedial alternatives including FS cost estimates.

1.2 SITE BACKGROUND

The Armstrong Building, OU2, is the last building remaining from Welsbach's operations. This three-story structure is located on the northwestern corner of Ellis and Essex Streets, Gloucester City, NJ on an active port, warehouse and logistics facility on the Delaware River. The property is currently owned by GMT Realty, Limited Liability Company (LLC). The port facility is operated by Gloucester Marine Terminal, LLC through Holt Logistics (Holt Logistics). The entire property is fenced and the only access point is through a gate with a guard booth staffed 24 hours a day. The Walt Whitman Bridge is located just north of the building, residential areas are located immediately east and southeast, and the Delaware River is located approximately 1,000 feet to the west. Refer to Figure 1 for a site location map.

Between the 1890s and 1940s, Welsbach manufactured gas mantles at its facility in Gloucester City, NJ. Beginning around 1895, Welsbach imported monazite ore to use as its source of the radioactive element thorium. Welsbach extracted thorium from the ore and used it in its gas mantle manufacturing process since thorium caused the mantles to glow more brightly when heated. Just after the turn of the 20th century, Welsbach was the largest producer of gas mantles and lamps in the United States, making up to 250,000 mantles per day. It appears that around 1915 Welsbach moved its operations from the property along the southwestern corner of Ellis and Essex Streets to the newly building Armstrong Building, along with other buildings on the north side of Essex Street. Welsbach went out of business in 1940. As shown on the June 1930 Sanborn map, Figure 2, the Armstrong Building was comprised of six connected buildings containing approximately 200,000 square feet (ft^2) of floor space. For reference in this report, the individual buildings are named per the designations on the Sanborn map (*e.g.*, W-0).[1] The Armstrong Building has three basement areas (*i.e.*, under a portion of building W-0 and under buildings W-2 and W-4) and three above-ground stories, and is constructed primarily of masonry and reinforced concrete.

From around 1915 until 1940, the Armstrong Building was one of the buildings used in the manufacturing of gas mantles. After Welsbach went out of business, the United States government took title to the northern section of the Welsbach property by virtue of a condemnation proceeding. Records indicate that the entire northern section of the property was sold to the Randall Corporation in 1948 and was leased to the Radio Corporation of America, Victor Division. In 1976, Holt Cargo Systems (Holt Cargo) purchased the former Welsbach property and used the Armstrong Building for offices, warehousing operations, and storage.

The Armstrong Building is over 90 years old and is in poor structural condition. Many of the exterior walls on the 2nd and 3rd floors of the building, as well as the 3rd floor ceiling, are open to the elements. In several of the rooms on the 3rd floor, the ceiling has collapsed, the roof is leaking, and there is extensive water damage. Moss and some plants are growing in the water damaged areas, and wildlife (*i.e.*, rodents, feral cats, pigeons) live on portions of the 2nd and 3rd floor. Due to the condition of the building, currently Holt Logistics only uses a few rooms on the 1st and 2nd floors. Some of the rooms on the 1st floor are used for offices, warehousing operations, and storage with a small portion of the 2nd floor of building "W-0" used for offices and training. The property owner currently plans to demolish the building at a future date. If not demolished, it is possible the entire building could be reused.

[1] Note that building "W-1" shown on the 1930 Sanborn map was previously demolished.

1.3 PREVIOUS INVESTIGATIONS

1.3.1 Integrated Environmental Management RI/FS

In May 1997, in an effort to expedite EPA's cleanup, Holt Cargo, the former owner of the Armstrong Building property, voluntarily entered into an Administrative Order on Consent (AOC) with EPA to conduct a Remedial Investigation/Feasibility Study (RI/FS) for the Armstrong Building. Holt Cargo contracted with Integrated Environmental Management, Inc. (IEM) to conduct this work; the investigation was conducted in 1998. Under the AOC, Holt Cargo submitted the following reports to EPA:

- *Remedial Investigation Report for the Armstrong Building*, July 1998 (IEM, 1998)
- *Comparative Analysis of Remedial Alternatives*, May 1999 (IEM, 1999)
- *Baseline Risk Assessment for the Armstrong* Building, January 2000 (IEM, 2000a)
- *Feasibility Study for the Armstrong Building*, January 2000 (IEM, 2000b)

IEM's investigations consisted mainly of alpha scans, which, to the extent possible, covered 100 percent (%) of the floor and 100% of the walls and columns to a height of six feet. At select locations with elevated alpha counts, IEM also collected fixed beta counts. Additional investigations included the collection of swipe samples and volumetric building material samples; a summary of the RI findings is provided in Section 1.4 of this FS.

1.3.2 Supplementary Remedial Investigation

Based on a review of IEM's RI, EPA identified several potential data gaps, including a number of wall surfaces which were covered by insulation and other materials that blocked IEM's investigation of these surfaces. Therefore, in 2010 ARCADIS/Malcolm Pirnie conducted a supplementary investigation at the Armstrong Building to collect a limited amount of additional data to close the data gaps identified in IEM's RI. Since IEM did not find any Welsbach-related contamination on the 1st floor of the building, supplementary investigations were only conducted on the 2nd and 3rd floors. The field investigation program for the supplementary investigation was outlined in the *Data Gap Plan OU2 – Armstrong Building, Welsbach/General Gas Mantle Contamination Superfund Site, Gloucester City, NJ,* prepared by ARCADIS/Malcolm Pirnie, June 2010, which was revised on August 1, 2010 and modified in the field based on practical considerations.

Surveys conducted during the supplementary RI included limited beta and/or gamma scans of the floors, walls, and columns, the collection of swipe samples and volumetric building material samples, and the collection of radon/thoron measurements. Details regarding these surveys are contained in the Supplementary RI Report.

1.3.2.1 Asbestos and Lead Screening for Health and Safety

For field investigation health and safety purposes, a screening-level asbestos and lead investigation was conducted during the Supplementary RI. Health and safety considerations specific to the field investigation program were outlined in the *HASP Addendum, Radiological Investigations in the Armstrong Building*, April 2010, prepared by ARCADIS/Malcolm Pirnie as an addendum to the *Accident Prevention Plan, Welsbach/General Gas Mantle Contamination Superfund Site, Camden and Gloucester City, New Jersey*, March 2010, also prepared by ARCADIS/Malcolm Pirnie. In October 2009, ARCADIS/Malcolm Pirnie conducted an investigation of the interior of the building for the presence of asbestos and lead in building materials, paints, and debris that could be disturbed during the investigation (Malcolm Pirnie, Inc., 2009). This screening-level investigation, conducted on the 1st, 2nd, and 3rd floors of the building and in a small basement at the southern end of building, included visual inspections and the collection and analysis of bulk samples of building materials, paints, and debris piles potentially containing asbestos and/or lead. The results of the investigation are briefly summarized below. Additional detail regarding this investigation can be found in the *Asbestos and Lead Screening Report, Armstrong Building, Gloucester City*, New Jersey (Malcolm Pirnie, Inc., November 2009) and in the RI Report (ARCADIS/Malcolm Pirnie, 2011).

Twenty-four bulk samples, including one suspect building material sample from what appeared to be fire-proof board on the 3rd floor and 23 debris pile samples from the basement, 1st, 2nd, and 3rd floors, were collected for asbestos analysis. The sample locations were selected based on the proximity of potential asbestos-containing materials (ACM[2]) /debris to floor and wall surfaces, the type of suspect material present (*i.e.*, friable vs. non-friable), and the ability to collect enough suspect ACM/debris for adequate laboratory analysis. The samples were analyzed by both polar light microscopy and transmission electron microscopy. ACM was detected in two floor debris pile samples from the 2nd floor (samples from Room 13 and Area B contained 3% chrysotile fibers) and three floor debris pile samples, including one containing pipe insulation debris, from the 3rd floor (a sample from Room 15 with pipe insulation contained 40% chrysotile fibers and two samples from Room 17 contained 2% chrysotile fibers).

Nine paint chip samples and 24 debris pile samples were collected for lead analysis. The paint chip samples were generally collected from areas where paint covered substantial surface areas and where the paint was determined to be in poor condition (*i.e.*, flaking and peeling). The debris pile sample locations were selected based on the proximity of the debris piles to floor and wall surfaces, the presence of visible paint chips in the debris, and the ability to collect enough debris for adequate laboratory analysis. The paint chip and debris pile samples were analyzed for total lead, the detection of

[2] ACM is identified as a material composed of asbestos, of any type, in an amount greater than 1% either alone or mixed with other fibrous or non-fibrous materials.

which likely originated in lead-based paint (LBP) or lead-containing paint (LCP)[3]. All paint chip samples were characterized as either LBP (four samples) or LCP (five samples). Total lead was detected in all 24 floor debris samples at concentrations ranging from less than 40 milligrams/kilogram (mg/kg) to 63,000 mg/kg.

1.4 NATURE AND EXTENT OF CONTAMINATION

1.4.1 Radiological Contaminants

The nature and extent of potential radioactive contamination discussed in this section is based on both the IEM RI and the ARCADIS/Malcolm Pirnie Supplemental RI. Radioactive contamination was not found on the 1st floor of the Armstrong Building. On the second floor, radioactive levels above the field investigation and/or screening levels were found in five of nine rooms on that level (Rooms 9, 10, 11, 13, and Area B). On the third floor, radioactive levels above the field investigation and/or screening levels were found in all nine rooms (Rooms 15, 16, 17, 18, 19, 20, 21, 22, and Area A). Survey and analytical levels are summarized in the respective RI Reports. A room by room summary is given in **Table 1-1**.

Table 1-1
RI Result Room by Room Summary

Room/Area	Floors	Walls	Columns
2nd Floor			
8	Unaffected	Unaffected	Unaffected
9	Affected	Affected	Affected
10	Affected	Affected	Unaffected
11	Affected	Affected	Affected
12	Unaffected	Unaffected	Unaffected
12a	Unaffected	Unaffected	No columns present
13	Affected	Affected	Unaffected
14	Unaffected	Unaffected	Unaffected
Area B	Unaffected	Unaffected	No columns present
3rd Floor			
15	Affected	Affected	Affected
16	Affected	Affected	Unaffected
17	Affected	Affected	Unaffected
18	Affected	Affected	Unaffected
19	Affected	Affected	Unaffected
20	Affected	Unaffected	Unaffected

[3] LBP is defined as paint that contains greater than or equal to 0.5% lead by dry weight [*i.e.*, $\geq$ 5,000 mg/kg or parts per million (ppm)]. LCP is defined as paint that contains less than 0.5% lead by dry weight (*i.e.*, $\leq$ 5,000 mg/kg or ppm).

Table 1-1 RI Result Room by Room Summary			
Room/Area	**Floors**	**Walls**	**Columns**
21	Affected	Affected	No columns present
22	Affected	Affected	No columns present
Area A	Affected	Affected	No columns present

Affected indicates that levels above the respective investigation levels were found during the radiological scans and/or fixed radiological count measurements and/or levels above the respective screening levels were detected in the swipe and/or volumetric samples.

The following additional information was obtained during the RIs:

- With the exception of Room 11, the volumetric building sample results indicate that radioactive contamination is predominantly due to thorium series radionuclides. The radioactive contamination in Room 11 appears to be associated with radium-226 (Ra-226).
- With one exception, the volumetric building material sample results indicate that contamination of building materials is superficial (*i.e.*, contained within the top 1/8 inch of the surface). One volumetric floor sample from Room 11, collected to a depth of 1-1/8 inch, had an elevated Ra-226 concentration.
- Building material contamination varied by room and by location within a room; however, locations within a room were not uniformly contaminated.
- Wipe sample results indicated the presence of removable contamination on the floors in Rooms 11, 13, 17, and 20.
- Removable contamination was not detected on any of the top horizontal surfaces of the pipes and heating, ventilation, and air conditioning (HVAC) components sampled.
- Radon (Radon-222) levels were below 2 picocuries per liter (pCi/L) and thoron (Radon-220) was not detected in any of the rooms tested.

1.4.2 Non-Radiological Contamination

During the ARCADIS/Malcolm Pirnie RI, ACM were detected in two floor debris pile samples from the 2nd floor (Room 13 and Area B) and three floor debris pile samples from the 3rd floor (Room 15 and Room 17) and all paint chip samples collected were characterized as either LBP or LCP. Based on these findings, it was assumed in this FS that construction debris and other wastes generated during the remediation may contain ACM and lead. Therefore ACM and LBP were included in this FS for the identification of ARARs and To Be Considered (TBC) guidelines. A cost was assumed for ACM and LBP characterization, abatement and disposal for the remedial alternatives, as described in Section 3.

1.5 CONTAMINANT FATE AND TRANSPORT

The primary radionuclides of concern at the Armstrong Building, Thorium-232 (Th-232) and Ra-226, are from the thorium and radium series decay chains, respectively. With half-lives of 14 billion years and over 1,600 years, respectively, both Th-232 and Ra-226 are extremely long-lived. Therefore, radioactive decay does not contribute significantly toward their degradation in the environment.

Radionuclide contamination in the Armstrong Building could be released to the environment through either event-specific processes, such as collapse, fire, or demolition, or through gradual processes, such as airborne migration of particulates. The primary factors affecting fate and transport of radionuclides in buildings are structural integrity, physical and chemical properties of the contaminated surfaces, and the chemical properties of the isotopes.

Due to the Armstrong Building's poor structural condition, the deterioration of the building is expected to continue over time. Accordingly, it is expected that the threat of a release of radioactive contamination to the environment will increase via one or more of the following release mechanisms:

- Fire – In the event of a fire, a potential airborne release of radioactive contamination (smoke) could impact emergency responders and/or off-Site receptors (i.e., residents, workers) adjacent to the Site. In addition, in the event of a fire, a physical hazard would be posed to port workers and emergency responders who would be summoned to respond.
- Building Collapse – In the event of a building collapse, it is expected that additional radioactive contamination would enter the environment via dust dispersal and increased weathering of exposed radioactive building materials and debris. In addition, in the event of a building collapse, a physical hazard would be posed to port workers present in the area during the collapse.

1.6 BASELINE RISK ASSESSMENT

As discussed previously, under Holt Cargo's AOC with EPA, IEM developed a Baseline RA in January 2000. Since the IEM Baseline RA is over ten years old, and there have been updates/improvements in modeling computer codes over the past decade, along with the identification of additional exposure scenarios and human receptors based on the current owner's planned future use of the Armstrong Building, ARCADIS/Malcolm Pirnie updated the Baseline RA. Data from both IEM's RI, as well as the ARCADIS/Malcolm Pirnie supplementary RI, were used to characterize the nature and extent of radioactive contamination in the Armstrong Building for the purpose of the ARCADIS/Malcolm Pirnie Baseline RA.

The ARCADIS/Malcolm Pirnie Baseline RA was conducted in general accordance with EPA's *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A)* (EPA, 1989) and other related guidance as cited throughout the assessment. The objectives of the Baseline RA, as outlined in RAGS, Part A (USEPA, 1989) were to:

- Evaluate baseline risks, currently and in the future, in the absence of remedial action and institutional controls.
- Provide a basis for determining the potential need for, and extent of, a possible remedial action.

Estimated incremental cancer risks are compared to the cancer risk range established in EPA's NCP, when ARARs are not available or are not sufficiently protective. For known or suspected carcinogens, the NCP established that acceptable exposure levels are generally concentration levels that represent an incremental upper-bound lifetime cancer risk in the range from 10^{-4} (*i.e.*, 1 in 10,000) to 10^{-6} (*i.e.*, 1 in 1,000,000) or less.

Potential receptors and exposure pathways identified for the Armstrong Building Baseline RA were based on current and future land use, the physical condition of the building, and the radioactive contamination identified. The exposure routes were evaluated as appropriate for the potential receptors. The following populations and scenarios were evaluated in the Baseline RA.

1.6.1 Building Reuse Exposure Scenarios

Under this scenario, exposure to indoor workers and resident adults and children was modeled, with the assumption the building would be renovated in the future for either commercial/industrial or residential use. Both of these scenarios were modeled using RESRAD-BUILD[4]. These scenarios were evaluated since the radionuclides of concern do not degrade significantly in the environment over time. Therefore, it is expected that radioactive contamination will be present in the Armstrong Building for the foreseeable future. Potential exposure pathways evaluated include external exposure, inhalation via radon/thoron or airborne dust, and ingestion.

Based on this evaluation, the following incremental lifetime cancer risks were calculated.

- Workers –
    - Above the upper bound of the risk range:
        - 5 in 10,000 (5E-04) for Room 11
    - Within the upper bound of the risk range:
        - 1 in 10,000 (1E-04) for Room 17
    - Within or below the risk range for all other rooms/areas

[4] The USDOE RESRAD-BUILD computer code, Version 3.5, developed by Argonne National Laboratory (ANL), was used in this evaluation.

- Resident Adults –
  - Above the upper bound of the risk range:
    - 3 in 1,000 (3E-03) for Room 11
    - 6 in 10,000 (6E-04) for Room 17
  - Within the upper bound of the risk range:
    - 3 in 10,000 (3E-04) for Room 9
    - 3 in 10,000 (3E-04) for Room 10
    - 2 in 10,000 (2E-04) for Room 13
    - 2 in 10,000 (2E-04) for Room 15
    - 3 in 10,000 (3E-04) for Room 21
    - 1 in 10,000 (1E-04) for Room 22
    - 2 in 10,000 (2E-04) for Area A
  - Within the risk range for all other rooms/areas
- Resident Children –
  - Above the upper bound of the risk range:
    - 6 in 10,000 (6E-04) for Room 11
  - Within the upper bound of the risk range:
    - 1 in 10,000 (1E-04) for Room 17
  - Within or below the risk range for all other rooms/areas

Therefore, under the worker scenario, the incremental lifetime cancer risk calculated for one room, Room 11, is greater than the upper bound of the risk range. Under the residential scenario, the incremental cancer risk for residents is greater than the upper bound of the risk range for two rooms, Rooms 11 and 17.

1.6.2 Building Demolition Exposure Scenarios

This scenario was modeled since the current owner plans to demolish the building at a future date. Potential receptors include demolition workers inside the building and hypothetical resident adults and children living in a residence built above buried debris from the demolished building. The demolition worker scenario was evaluated with RESRAD-BUILD and the residential scenario was evaluated with RESRAD[5]. Potential

[5] The USDOE RESRAD computer code, Version 6.5, developed by ANL, was used in this evaluation.

exposure pathways evaluated include external exposure, inhalation via radon/thoron or airborne dust, and ingestion.

Based on this evaluation the following incremental lifetime cancer risks were calculated.

- Demolition Workers -
    - 2 in 100,000 (2E-05) for demolition of all affected rooms/areas, which is within the risk range
- Hypothetical Resident Adults –
    - 1 in 10,000 (1E-04) (at time 100 years) with the radon model turned off, which is within the upper bound of the risk range
    - 2 in 10,000 (2E-04) (at time 100 years) with the radon model turned on, which is within the upper bound of the risk range
- Hypothetical Resident Children –
    - Within or less than the risk range whether the radon model was turned off or turned on

1.6.3 Catastrophic Release Exposure Scenario

Due to the deteriorated condition of the Armstrong Building, a catastrophic release is possible through several mechanisms including fire or building collapse. Therefore, a catastrophic release scenario was evaluated using HotSpot Health Physics Code (HotSpot)[6]. The population evaluated included the general public in the vicinity of, and downwind of the building, with potential exposure pathways including inhalation and external exposure. Based on this evaluation, the highest incremental lifetime cancer risk is 2 in 10,000 (2E-04) for a receptor on the Walt Whitman Bridge, which is within the upper bound of the risk range.

1.7 IEM FEASIBILITY STUDY

As discussed in Section 1.3.1, under Holt Cargo's AOC with EPA, IEM developed an FS for the Armstrong Building in January 2000. The PRG used by IEM to calculate the area requiring decontamination was 570 disintegrations per minute per square centimeters (dpm/cm^{2}), which was based on U.S. Nuclear Regulatory Commission (USNRC) NUREG- 1500 (1994) guidance. IEM's FS screened various remedial technologies and five Remedial Action Alternatives were developed, including:

- Alternative 1 - No Action

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[6] HotSpot Version 2.07.1, developed by the U.S. Department of Energy (USDOE) and supported by Lawrence Livermore National Laboratory's National Atmospheric Release Advisory Center (NARAC), was used in this evaluation.

- Alternative 2 - Surface sealing (engineered control)
- Alternative 3 - Building demolition, limited decontamination (building removal)
- Alternative 4 - Partial decontamination and demolition (partial decontamination)
- Alternative 5 - Decontamination and reuse of building (complete decontamination).

Three options were also developed for each of the Alternatives 3, 4, and 5 to provide for various reuse and disposal options for the contaminated building materials and demolition rubble. Based on its screening, IEM determined that the preferred remedial alternative was Alternative 5, Building Decontamination.

Since IEM's FS is over 10 years old, ARCADIS/Malcolm Pirnie prepared this FS to consider the PRG, ARARs, TBCs, and remedial technologies that may have been updated/improved since that time. The remainder of this report presents the results of the ARCADIS/Malcolm Pirnie FS.

1.8 REPORT ORGANIZATION

This report is comprised of the following sections:

- Identification and Screening of Technologies (Section 2)
- Development and Screening of Alternatives (Section 3)
- Detailed Analysis of Remedial Alternatives (Section 4)
- References (Section 5)
- Glossary of abbreviations and acronyms (Section 6)

2 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

2.1 POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO-BE-CONSIDERED GUIDELINES

Section 121(d) of CERCLA (42 United States Code [U.S.C.] § 9621[d]), as amended, states that remedial actions at CERCLA sites must attain (or the decision document must justify the waiver of) any federal or more stringent state environmental standards, requirements, criteria, or limitations determined to be legally *applicable or relevant and appropriate*.

Applicable requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that specifically address circumstances at a CERCLA site." The requirement is applicable if the jurisdictional prerequisites of the standard show a direct relationship when objectively compared to the conditions at the site. An applicable federal requirement is an ARAR. An applicable state requirement is an ARAR only if it is more stringent than federal ARARs. (40 CFR §300.5).

If the requirement is not legally applicable, then the requirement is evaluated to determine whether it is relevant and appropriate. *Relevant and appropriate* requirements "are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable to a contaminant, action or location at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site." A requirement must be determined to be both relevant *and* appropriate to be considered an ARAR (40 CFR §300.5).

The criteria for determining relevance and appropriateness (40 C.F.R. § 300.400(g)(2)) include the following:

- The purpose of both the requirement and the CERCLA action.
- The medium regulated or affected by the requirement and the medium contaminated or affected at the CERCLA site.
- The substances regulated by the requirement and the substances found at the CERCLA site.
- The actions or activities regulated by the requirement and the response action contemplated at the CERCLA site.
- Any variances, waivers, or exemptions of the requirement and their availability for the circumstances at the CERCLA site.

- The type of place regulated and the type of place affected by the release or CERCLA action.
- The type and size of structure or facility regulated and the type and size of structure or facility affected by the release or proposed in the CERCLA action.
- Any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resources at the CERCLA site.

A requirement may be "applicable" or "relevant and appropriate," but not both. ARARs must be identified on a site-specific basis and involve a two-part analysis: first, a determination whether a given requirement is applicable; then, if it is not applicable, a determination whether it is both relevant and appropriate. Some regulations may be applicable or, if not applicable, may still be relevant and appropriate. When the analysis determines that a requirement is both relevant and appropriate, such a requirement must be complied with to the same degree as if it were applicable.

To qualify as a state ARAR under CERCLA and the NCP, a state requirement must be:

- A state law or regulation;
- An environmental or facility siting law or regulation;
- Promulgated (of general applicability and legally enforceable);
- Substantive (not procedural or administrative);
- More stringent than federal requirements;
- Identified in a timely manner; and
- Consistently applied.

To constitute an ARAR, a requirement must be substantive. Therefore, only the substantive provisions of requirements identified as ARARs in this analysis are considered to be ARARs. Permits are considered to be procedural or administrative requirements. Provisions of generally relevant federal and state statutes and regulations that were determined to be procedural or non-environmental, including permit requirements, are not considered to be ARARs.

Non-promulgated advisories or guidance issued by federal or state governments are not legally binding and do not have the status of ARARs. Such requirements may, however, be useful and are "TBC". *TBC requirements* complement ARARs but do not override them. They are useful for guiding decisions regarding cleanup levels or methodologies when regulatory standards are not available.

ARARs are generally divided into three categories to aid in their identification. Some ARARs do not fall precisely into one group or another. ARARs are identified on a site-specific basis for remedial actions where CERCLA authority is the basis for cleanup.

- **Chemical-specific requirements** are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values identify the acceptable concentration of a chemical that may be found in, or discharged to, the environment.
- **Action-specific requirements** are technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes.
- **Location-specific requirements** are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they occur in special locations.

2.1.1 Site-Specific Information Affecting ARARs/TBCs

To determine what ARARs/TBCs are pertinent to the Armstrong Building, the following information was considered:

- The following radionuclides of concern were identified in the Armstrong Building: Th-232 in Rooms 9, 10, 13, 15, 17, 21, and Area A and Ra-226 in Room 11.
- ACM have been found in various samples collected from the building.
- Analyses of paint chip samples from the building have indicated the presence of LBP and LCP. Analyses of debris samples have indicated total lead concentrations up to 63,000 mg/kg.
- Toxicity characteristic (TC) wastes are those wastes that exhibit a Toxicity Characteristic Leaching Procedure (TCLP) concentration greater than the regulatory level given in 40 CFR 261.3. For lead, the TCLP regulatory level is 5 milligrams per liter. Although none of the paint chip samples from Armstrong Building have been analyzed for TCLP parameters, total lead results can be converted to TLCP results through application of a factor (RCRA rule-of-20) that converts the detected solid phase concentration to a liquid phase concentration. The liquid phase concentrations determined through the conversion are conservative values since the conversion factor assumes that all of the analyte will leach from the solid to liquid phase during the extraction process. Based on this, many of the paint and debris samples collected from the building would be considered TC wastes.

2.1.2 Chemical-Specific ARARs

- 40 CFR, Subpart M 61. 145 and 150 National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations for Asbestos. Standard for renovation/demolition of and waste disposal for asbestos containing materials for manufacturing, fabricating, demolition, renovation, and spraying operations. This requirement is considered applicable.

- 40 CFR 261 Subtitle C RCRA regulation for the disposal of LBP waste exhibiting TC for lead as relevant and appropriate requirement due to the presence of lead paint. This requirement is considered applicable.
- N.J.A.C. 7:26-2.12 Relevant and appropriate requirements for disposal of regulated asbestos containing waste materials. This requirement is applicable.
- N.J.A.C. 7:26-2.13(g) Construction and Demolition Waste rules for the handling and disposal of ACM and LBP debris depending on the percentage of asbestos and or lead contained in the materials. This requirement is applicable.

2.1.3 Action-Specific ARARs

- 10 CFR 20.2002 establishes alternative disposal methods and facilities for low level activity radioactive waste. This regulation is potentially applicable.
- 40 CFR 300 NCP requirement that "remediation goals shall establish acceptable exposure levels that are protective of human health and the environment" [§300.430(e)(2)(i)] and that "for known or suspected carcinogens, acceptable exposure levels are generally concentrations that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} using information on the relationship between dose and response" [§300.430(e)(2)(i)(A)(2)]. This requirement is applicable.
- 49 CFR 171-173 U.S. Department of Transportation regulations governing all modes of hazardous materials transportation, including packing, repacking, handling, labeling, marking, placarding, and routing. This requirement is applicable.
- 29 CFR 1910 Radiation exposure for occupational workers, specifically regarding ionizing radiation (§1910.1096). This requirement is applicable.
- 40 CFR 61.145 require that the Notification and description of the work practices and engineering controls to be used to comply with the requirements of the asbestos NESHAP including asbestos removal and waste handling emission control procedures. This requirement is applicable.
- 40 CFR Part 262 Transportation of hazardous wastes, if the TC of the LBP debris makes it a characteristic hazardous waste. This requirement is applicable.
- 40 CFR Part 268 Land Disposal Restrictions related to the disposal of LBP materials/debris as a characteristic hazardous waste. This requirement is applicable.
- N.J.A.C. 7:26-3.5 requirements for the transportation of asbestos-containing materials. This requirement is applicable.

2.1.4 Location-Specific ARARs

- National Historic Preservation Act. This act is potentially applicable.

2.1.5 TBC Considerations

- 40 CFR 192 §192.12(b)(1) and §192.41 (b), which provide combined exposure limits for cleanup of radon decay products in buildings at inactive uranium processing sites designated for remedial action.
- 40 CFR 192 §192.12(b)(2), which provides concentration limits for cleanup of gamma radiation in buildings at inactive uranium processing sites designated for remedial action.
- OSWER Directive No. 9200.4-18; EPA, 1997, EPA's Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, which indicates that if a dose assessment is conducted, 15 millirem/year effective dose equivalent (EDE) should generally be the maximum dose limit for humans.
- EPA's A Citizen's Guide to Radon (EPA, 2009) which contains an indoor exposure guideline for radon of 4 pCi/L of air.
- USNRC's working draft regulatory guide on release criteria for decommissioning, specifically radionuclide-specific surface concentrations at a specified annual EDE of 15 millirem per year (mrem/year) (USNRC, 1994).
- 40 CFR, Subpart E - Residential Property Renovation, Chapter 745 Lead-Based Paint Poisoning Prevention in Certain Residential Structures, §745.85 Work practice standards.
- N.J.A.C. 7:26D-7 New Jersey Remediation Standards, Appendix 4, regarding lead contamination and remediation, an alternative soil remediation standard (ARS) for the Ingestion-Dermal exposure pathway for a site or an area of concern.
- New Jersey Department of Environmental Protection (NJDEP) Guidance on Lead-based Paint Abatement Debris Disposal (Updated 01/13/2004).
- NJDEP Guidance Document for the Management of Asbestos-containing Material (ACM**) (**Updated 06/17/2009).
- N.J.A.C. 7:28, New Jersey Radiation Protection Programs, which incorporates by reference 10 CFR Part 20.
- 10 CFR 20 §20.2003, Radioactive waste at the former Welsbach facility is considered to be both naturally-occurring radioactive material and "by-product" material which is defined as "the tailings of wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content".

2.2 REMEDIAL ACTION OBJECTIVES

As previously discussed, the Armstrong Building, OU2, is over 90 years old and is in poor physical condition with many of the exterior walls on the 2nd and 3rd floors, along with the 3rd floor ceiling, open to the elements. Due to the condition of the building, only a few rooms on the 1st and 2nd floors are currently being used. Although the property owner plans to demolish the building at a future date, it is possible the entire building could be reused.

Radioactive levels above the field investigation and/or screening levels have been found in five of nine rooms on the 2nd floor (Rooms 9, 10, 11, 13, and Area B) and in all rooms/areas on the 3rd floor (Rooms 15, 16, 17, 18, 19, 20, 21, 22, and Area A).

Based on the RI and Baseline RA results, remedial actions appear to be warranted for future protection of human health and the environment for the following reasons:

- Remediation workers, waste haulers, and disposal facility personnel may be exposed to radiological contaminants during remediation activities.
- In the absence of remediation, potential catastrophic release mechanisms (*e.g.*, fire, building collapse) may pose a health threat to residents and workers located adjacent to the Armstrong Building OU2.
- In the absence of remediation, future potential workers and/or residents could be exposure to radiological contamination during reuse of the building.

Therefore, the RAOs developed for the Armstrong Building OU2 to protect human health and the environment include:

- Preventing exposure from radiological contamination on building surfaces.
- Preventing future release of radioactive contamination from the Armstrong Building to the environment.

2.3 PRELIMINARY REMEDIATION GOALS

PRGs are designed to achieve cleanup levels that are protective of human health and the environment. In its 1999 FS, IEM identified USNRC NUREG 1500 as a Relevant and Appropriate Requirement. NUREG 1500 indicated a surface activity cleanup level of 571 dpm/100 cm^2 for Th-232 (with decay product radionuclides). However, in 2006, NRC consolidated its decommissioning guidance published in numerous older NUREGs, including NUREG 1500, into NUREG 1757 which specifies a risk-based approach to developing release levels. Therefore, for the Armstrong Building, Site-specific PRGs were developed based on both IEM's and ARCADIS/Malcolm Pirnie's RI results, as well as ARCADIS/Malcolm Pirnie's Baseline RA.

PRGs, which are risk-based surface activities, were derived separately for Th-232 and Ra-226 since both are radionuclides of concern. Derivation of risk-based surface activities was accomplished by iteratively re-running RESRAD-BUILD[7] and modifying radionuclide-normalized source surface activities for those rooms/areas evaluated in the Building Reuse/Residential scenario of the Baseline RA (ARCADIS/Malcolm Pirnie, 2011) that had cancer risks greater than the upper bound of the risk range (*i.e.*, Rooms 9, 10, 11, 13, 15, 17, 21, and Area A). The model setups from the Baseline RA for reasonable maximum exposure (RME) of a resident adult (24-year exposure) and a resident child (6-year exposure) in the affected room were used. As described in the Baseline RA, each of these receptors was actually modeled as two component receptors, one spending most of the time in the center of the room and a second spending some time in a corner of the room. The cancer risks for the two component receptors for both the resident adult and resident child were then summed to estimate the total cancer risk for the individual in the room.

The prospective source activities were iteratively modified until a target cancer risk of 10^{-4} was achieved.

The radionuclide-normalized risk-based surface activities are presented in **Table 2-1**. The risk-based surface activity selected for Th-232 was 500 dpm/100 cm^2, based on the lowest derived values for Rooms 9, 10, 13, 15, 17, 21, and Area A, and the risk-based surface activity for Ra-226 was 1,000 dpm/100 cm^2, based on Room 11.

Based on these calculations, the PRG for all radionuclides of concern for the Armstrong Building in this FS is 500 dpm/100 cm^2, not including background. This value was selected for the following reasons:

- Alpha, beta, and gamma scans, which are used to detect radiation on building surfaces, are not isotopic-specific. Therefore, isotopic-specific PRGs cannot be used.
- The majority of the Rooms/Areas are contaminated with thorium and the thorium PRG is more conservative than the radium PRG.

[7]Two tools used to develop PRGs, RESRAD-BUILD and the current online version of the EPA Preliminary Remediation Goals for Radionuclides in Buildings (BPRG) calculator (EPA 2009) (developed by the Oak Ridge National Laboratory), were evaluated to determine which tool should be used for Armstrong Building. Based on this evaluation, it was determined that while RESRAD-BUILD and the BPRG calculator compare favorably, RESRAD-BUILD is better able to model future use scenarios and is more site specific. Refer to **Appendix A** for the *Technical Memorandum, A Comparison of RESRAD-Build with the Online EPA BPRG Calculator Tool for the Armstrong Building at the Welsbach/GGM Superfund Site*, June 2011, developed by USACE, for additional information regarding this comparison.

Table 2-1
Radionuclide-Normalized Risk-Based Surface Activities

Room/ Area	Radionuclide of Interest	Radionuclide-Normalized Risk-Based Surface Activity at 1E-04 Risk		Corresponding Total Effective Dose Equivalent
		dpm/m^2	$dpm/100\ m^2$	mrem/year
9	Th-232	51,000	510	5
10	Th-232	54,000	540	5
11	Ra-226	104,000	1040	4
13	Th-232	55,000	550	5
15	Th-232	58,000	580	5
17	Th-232	50,000	500	5
21	Th-232	53,000	530	5
A	Th-232	61,000	610	5

2.4 GENERAL RESPONSE ACTIONS

General response actions are proposed for containment or removal of radioactively contaminated building surfaces at the Armstrong Building with the intent of satisfying the RAOs stated in Section 2.2 and meeting the requirements of the NCP. Each RAO can be accomplished by implementing one or more general response actions. The NCP sets out the types of remedies that are expected to result from the remedy selection process defined below:

- Treat principal threats, wherever practicable. Principal threats are characterized as the following. No principal threat wastes have been identified in the Armstrong Building.
    - Areas contaminated with high concentrations of toxic compounds
    - Liquids and other highly mobile materials
    - Contaminated media that pose significant risk of exposure.
    - Media containing contaminants several orders of magnitude above health based levels.
- Appropriate remedies often will combine treatment and containment.
- Containment will be considered for wastes that pose a relatively low long-term threat or where treatment is impracticable.
- Institutional controls (ICs) are most useful as a supplement to engineering controls for short- and long-term management.
- Innovative technologies should be considered if they offer the potential for comparable or superior treatment performances or lower costs for similar levels of performance than demonstrated technologies.

2.4.1 General Response Action for Armstrong Building OU2

A general response action is a raw form of a remedial alternative that is proposed then refined as the FS process proceeds. For this Site, general response actions that address potential future human and environmental exposure to radioactive materials include the following:

- No Action
- Institutional Controls
- Containment (Engineering Controls)
- Active Remediation – Decontamination and Demolition

Each of these general response actions is discussed in the following sections.

2.4.1.1 No Action

The no action response provides a baseline for evaluating the remedial alternatives available as required by the NCP. The no action response would not be effective in preventing human exposure to radiological contaminants; however, in accordance with CERCLA Section 121(c), a review/reassessment of the conditions at the Site is required at 5-year intervals to determine if other remedial action efforts are warranted.

2.4.1.2 Institutional Controls

ICs represent non-engineered administrative or legal controls that limit land or resource use and are considered a limited action remedial alternative. ICs can be a stand-alone remedy or can serve as a supplement to an engineering control remedial action throughout all stages of the cleanup process. The use of ICs as a sole remedy is not encouraged unless all other remedial actions are determined to be impractical. ICs are particularly beneficial when incorporated as a layered component of the cleanup process to provide overlapping assurances of protection from contamination.

2.4.1.3 Containment (Engineering Controls)

Containment response actions, which include physical barriers, are used to isolate the contaminated media and to restrict migration of contaminants. Since containment response actions do not have a treatment component, they do not reduce the concentration or volume of contaminants. Containment options may be combined with source control measures to form feasible alternatives.

2.4.1.4 Active Remediation - Decontamination and Demolition

The active restoration general response action involves removing radiological contaminated building materials to levels below the PRG. Decontamination or demolition would remove the radiological contaminants.

2.5 Identification, Screening, and Evaluation of Remedial Technologies

In accordance with *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988 OSWER Directive No. 9355.3-01), remedial technologies were selected and screened based on the general response actions to satisfy the RAOs and achieve the PRG. This evaluation is based on three criteria; effectiveness, implementability, and relative cost, with effectiveness being the primary driver.

- <u>Effectiveness</u> - focuses on the potential effectiveness of process options in handling the estimated volume of media and meeting the remediation goals; the potential impacts to human health and the environment during implementation; and how proven and reliable the process is with respect to the contaminants and conditions at the site.
- <u>Implementability</u> - evaluates the technical and institutional feasibility of implementing a process.
- <u>Cost</u> - plays a limited role in this screening. The cost analysis is based on engineering judgment, and each process is evaluated as to whether costs are high, low, or medium relative to the other options in the same technology type.

2.5.1 Technology Identification/Description

2.5.1.1 Engineered/Institutional Controls

Engineered controls for surficial radioactive contamination include installation of an engineered physical barrier to prevent contact and minimize exposure to the underlying contaminated material. Barriers may include the use of paint or other coatings, steel plates, or concrete. ICs are non-engineered instruments, such as administrative and legal controls (*e.g.*, land use zoning restrictions, environmental covenants) that help minimize the potential for human exposure to contamination and/or protect the integrity of the remedy. The NCP emphasizes that ICs are meant to supplement engineering controls and will rarely be the sole remedy at a site.

2.5.1.2 Decontamination

Decontamination, which is a proven technology for the removal of radiological contamination from the surfaces of facilities and equipment, may be accomplished using a variety of chemical and physical techniques. According to EPA (2006), the objectives of decontamination are to:

- Reduce radiation exposure.
- Enable reuse of facilities and equipment.
- Reduce the amount of material (equipment, construction and related debris) requiring expensive disposal.
- Restore a site or facility to productive use.

- Remove contaminants prior to return to use, further treatment, modifications, protective storage, or longer-term management and disposal.
- Reduce the amount of residual radioactivity to be protective of public and worker health and safety, and the environment.

The nature and extent of radiological contamination (*i.e.*, Th-232 and Ra-226 concentrations along with the depth the contamination extends into the building materials) determine the decontamination technologies that were selected for evaluation in this FS. As such, the technologies were selected based upon the following criteria:

- Effectiveness in removing radiological contamination from structural materials, including concrete floors and columns, and brick walls.
- Capability of removing radiological contamination in relatively thin layers (approximately 1/8 inch for the majority of surfaces to 1-1/8 inches for select areas) to minimize the amount of generated waste requiring disposal.
- Minimization of airborne dust generated by its operation, both to limit the spread of contamination and to reduce the possibility for worker intake.
- Technical feasibility using commercially available equipment and processes that have been demonstrated for similar building conditions and contamination.
- Implementability within a reasonable timeframe.

Both physical and chemical decontamination methods are available. Physical methods generally involve the use of abrasives or other physical activities to remove layers of material while chemical methods typically destroy the chemical bond between the surface layer of the structure and underlying layers so that the surface layer can be easily removed. The performance of a given technology is highly dependent on a variety of factors concerning the circumstances of the contamination, including contaminant type, contaminant chemical and physical properties, contaminant origin and history, depth of penetration, and surface material properties (EPA 2006).

For those methods that have not yet been demonstrated to be effective for a specific surface and associated coating, treatability studies are critically important in determining if the method is feasible. Depending on the type of decontamination method, surface preparation may be required for the targeted cleanup areas based on the different types of floor, wall and column coverings present (*e.g.*, paint, tiles and mastic, wallboard, plywood and lumber, Styrofoam, and plastic sheeting) and other contaminants or wastes (*e.g.*, ACM, bird droppings, soil, moss). The following are descriptions of each decontamination method and a discussion of its relative effectiveness. A summary of the advantages and disadvantages of the two decontamination methods is given in **Table 2-2**.

2.5.1.2.1 Physical Decontamination Methods

Physical decontamination, also referred to in the literature as mechanical decontamination, is the removal of surface radiological contamination by physical processes. Physical decontamination techniques can be divided into surface cleaning and surface removal techniques (EPA, 2006).

- Surface cleaning techniques - include brushing, wiping, flushing, vacuuming, and strippable coatings, where the surface remains intact but contamination on the surface is mechanically dislodged.
- Surface removal techniques - include grinding, blasting, scabbling, shaving, spalling, peening, and scaling, where the contamination is removed by removing an entire layer of the surface.

Two abrasion technologies are typically used for surface decontamination: scabbling and blasting.

- Scabbling - involves shearing off a layer of a surface using an abrasive head, moving in either a reciprocating or a rotating motion. The head(s) that provide the shearing force can be attached to either a general-purpose tool (*e.g.*, air hammer) or a dedicated machine. Dust control becomes an important issue during scabbling; thus, some machines are equipped with skirts to contain the generated dust, and with dust collection systems to filter the dust-laden air prior to discharge.
- Blasting - uses a jet of abrasive material to remove the surface layer off of a structure. The abrasive comes in a variety of forms, ranging from hard material (*e.g.*, steel shot or sand) to specialty materials (*e.g.*, dry ice pellets, ice pellets, sponge pieces, or plastic beads). As with scabbling techniques, dust control is an important consideration during surface blasting.

Physical decontamination can be either an alternative or a complement to chemical decontamination.

2.5.1.2.2 Chemical Decontamination Methods

Chemical agents are widely used in the nuclear and related industries as decontaminants, primarily to remove fixed contamination. Chemical decontamination is a very versatile approach to radiological decontamination since various chemical agents may be used to chemically transform and/or remove contamination. However, its effectiveness may be limited since the same chemical processes that attack the contaminant can also attack the surface material on which the contaminant resides. The ability of the chemicals to work efficiently on both glazed surfaces (e.g., brick, tile) and bare structure (e.g., concrete) and the means of controlling the depth of penetration of the chemical into the structural surface are also potential risk factors. There are potential waste disposal considerations as well, such as waste classification (i.e., potential mixed wastes) and meeting the acceptance criteria for the identified disposal facility (EPA, 2006).

Three types of chemical phenomena account for most chemical decontamination techniques: acid or alkaline dissolution, oxidation/reduction (redox) reactions, and chelation (complexation, sequestration) reactions. These three are not mutually exclusive and, in fact, are often used together, both simultaneously and sequentially. While the ability to combine techniques adds to the capabilities of chemical decontamination, it also adds complexity to its use and requires that a clear understanding of the advantages and disadvantages be obtained.

Table 2-2
Summary of Advantages and Disadvantages of Physical and Chemical Decontamination

Physical Decontamination		Chemical Decontamination	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Ease of Use			
While applicable to almost all surfaces, these technologies are best applied to large, regular, unencumbered surfaces.	The more difficult it is to remove the surface the less advantageous physical decontamination becomes (*e.g.*, it is easy to remove a plaster or grout surface and it is difficult and expensive to remove a steel surface).	Under the right circumstances, chemical decontamination can be relatively quick and simple.	Due to the complexity of the systems used, chemical decontamination often requires the availability of in-depth chemical expertise. This is true both for the decontamination itself and for ancillary concerns, such as waste stream management.
Surface preparation is usually not an issue since the entire surface is removed.	Though surface preparation is relatively easy, the immediate environment in which the decontamination is taking place must be properly prepared, including the removal of obstacles or encumbrances such as piping or conduit if the technology requires a flat, unhindered surface.	It is similar to classical cleaning in the general industry and can draw on much of the same operational experience.	Higher temperatures are sometime needed to increase the kinetics of the decontamination.
	Access to a surface, along with the complex geometry of certain surfaces, can be a significant issue.	It has the potential to remove contaminants from areas with restrictions to physical access, such as interior surfaces, crevices, joints, piping, remote internal volumes, hidden parts, complex geometries.	Treatability studies would be required to develop a site-specific formulation for chemical decontamination. The time required to complete these studies means that the technology may not be available as quickly as physical decontamination methods.
Disposal			
Waste management tends to be relatively simple since the removed surface material can be collected directly and routed to waste disposal rather than requiring secondary treatments (*e.g.*, ion exchangers).	Generated waste volumes can be larger than with chemical decontamination methods, especially when deep surface removal is required or when large amounts of additives, such as abrasion media, are involved.		This technology generates liquid waste streams that may require treatment (neutralization, ion exchange, precipitation, filtration, evaporation) and can generate further secondary waste streams such as spent ion exchangers. Treatment of the secondary waste streams can add significantly to the cost.

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Table 2-2
Summary of Advantages and Disadvantages of Physical and Chemical Decontamination

Physical Decontamination		**Chemical Decontamination**	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
			This technology often generates mixed waste.
Health and Safety			
	These technologies often work by the physical abrasion of the surface; therefore, airborne emission of abraded particulates is an operational problem that must be addressed either directly by the technique or by ancillary measures (*i.e.*, collection systems such as skirts and/or vacuum filtration systems).	This technology usually involves little or no airborne contamination.	Safety concerns arise with the use of hazardous materials such as strong acids and oxidizers and with the production of hazardous byproducts such as hydrogen.
	These technologies tend to be more hands-on, requiring workers to operate tools in the immediate vicinity of the contaminated surface, thereby, requiring greater general attention to safety and health concerns due to the higher exposure dosages.		If not performed properly, chemical decontamination can increase exposure risks.
Effectiveness			
For some surfaces, physical decontamination is the only choice. The most common example is a porous surface such as concrete on which no barrier layer was placed and where contamination has reached deep within the matrix.	These technologies are destructive to the surface being cleaned, so they are either inapplicable to facilities or equipment requiring reuse or will entail a subsequent surface refinishing operation.	Decontamination factors of over 10,000 may be achieved.	For porous surfaces, a chemical approach is rarely successful and may worsen the situation by driving the contamination even deeper below the surface. By mobilizing the contaminant, there is increased risk of downstream recontamination and cross contamination of equipment, and increased risk of environmental consequences in the event of accidental releases.

Table 2-2
Summary of Advantages and Disadvantages of Physical and Chemical Decontamination

Physical Decontamination		**Chemical Decontamination**	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Physical decontamination can usually achieve higher decontamination factors than chemical decontamination because it is capable of removing the contaminated surface in its entirety.	Physical decontamination technologies have no radionuclide or chemical specificity.	When properly performed, it can have minimal effects on equipment and surfaces thus allowing easy reuse.	It is not usually effective on porous, painted, or glazed surfaces.
		With proper selection of chemicals, almost all radionuclides can be removed from contaminated surfaces.	Physical removal methods, like those described in the previous subsection, may still be needed to remove the surface layer once the chemical degradation is completed.
		It can be relatively inexpensive when additional equipment is not required.	
Cost			
The cost of scabbling methods are generally lower than those for blasting methods because blasting generates a larger volume of disposal material due to the use of abrasives needed for blasting.	With the exception of scabbling methods that employ dust collection systems (*i.e.*, skirts and/or vacuum filtration systems), this technique must include the cost for erecting and maintaining containment, for the higher levels of personal protective equipment (PPE), and for the larger volumes of waste disposal.		Overall, costs for chemical decontamination are typically equivalent to costs for physical decontamination. However, chemical contamination costs tend to be more variable due to the nature and extent of contamination, differences in building material substrates, the level of treatability testing required, and the number of full-scale treatments required.
			Liquid wastes, which typically require solidification/stabilization, and may require special waste classification and handling for transportation and off-site disposal, are generated with this technique.

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2.5.1.2.3 Estimated Decontamination Volumes

To determine costs, the volumes of material to be removed during decontamination of demolition were estimated. For decontamination, the following steps were used to calculate volume.

- As the PRG used by IEM in their FS Report to calculate the areas requiring decontamination is similar to the PRG developed for this FS[8], these surface areas were used as the basis of the decontamination volume estimate in each of the rooms.
- To determine volumes, the depth of contamination into the building materials was assumed to be 1-1/8 inch (0.09 foot) in Room 11 and 1/8 inch (0.01 foot) in all other rooms/area.
- This volume was increased by a factor of two (100%) to account for:
  - The slight difference in IEM's and ARCADIS/Malcolm Pirnie's PRGs.
  - Areas that were inaccessible during IEMs investigation due to cover materials.
  - Over-excavation of the material during decontamination since it is not possible to remove exactly 1/8 inch, in an exact polygon.
  - Uncertainties in surface area polygons estimated from radiological scans.
- The volume was further increased by a factor of two (100%) to account for additional material generated during decontamination (*e.g.*, for blasting media used in physical decontamination) and waste stabilization for dusts, powders, and/or liquid wastes generated during decontamination.

Refer to **Table 2-3** for a summary of the estimated decontamination waste quantities.

Table 2-3
Summary of Estimated Remediation Material Quantities

Room/ Area[1]	IEM Identified Surface Area Requiring Cleanup (ft^2)	Volume (cy)	Field Uncertainty Factor (cy)	Decontamination Uncertainty Factor (cy)	Total Volume (cy)
9	664	0.25	0.24	0.49	0.98
10	3,405	1.26	1.26	2.52	5.04

[8] As discussed in IEM's FS Report, the PRG used by IEM to calculate the area requiring decontamination is 570 dpm/cm^2, which is similar to the PRG developed for this FS (500 dpm/cm^2, not including background). IEM's value was based on USNRC NUREG- 1500 (1994) guidance; this guidance has subsequently been retracted.

Table 2-3
Summary of Estimated Remediation Material Quantities

Room/ Area[1]	IEM Identified Surface Area Requiring Cleanup (ft^2)	Volume (cy)	Field Uncertainty Factor (cy)	Decontamination Uncertainty Factor (cy)	Total Volume (cy)
11	3,405	11.35	11.35	22.7	45.4
13	800	0.30	0.29	0.58	1.19
15	241	0.09	0.09	0.18	0.36
17	13,217	4.90	4.89	9.79	19.6
21	8,880	3.29	3.29	6.58	13.2
A	3,186	1.18	1.18	2.36	4.72
Total					**90**

Note:
1 – IEM combined the surface Areas for Rooms 10 and 11. Since different decontamination depths were assumed for these two rooms in this FS, the surface area was separated in this report.

2.5.1.3 Demolition

Demolition is the tearing down of buildings by sawing, air hammer, explosives, shearing, tripping, or using heavy construction equipment (*e.g.*, excavator or a crane with a wrecking ball). Demolition is a proven technology for the removal of radiological contamination from the surfaces of facilities and equipment. Demolition of radiologically contaminated buildings either requires use of containment and monitoring measures to prevent migration of fugitive dust, or may be coupled with decontamination technologies to remove contaminated building surfaces prior to demolition. This technology would require radiological surveys during its implementation to segregate demolition rubble and other building equipment, as well as waste classification testing prior to disposing of these materials. As demolition does not treat or destroy the radiological contaminants, this technology would need to be combined with off-site treatment or disposal as a remedial alternative.

Demolition quantities were estimated using engineering judgment to estimate building dimensions in the absence of detailed surveys or building drawings (floor, wall, and ceiling thicknesses; foundations, roofs, and HVAC equipment and ductwork). The total quantity of material estimated for complete building demolition is approximately 19,500 cubic yards (cy), which is similar to the quantity estimated in IEM's FS of 20,000 cy. Additional details regarding the updated estimate of remediation material quantity estimates for surface decontamination and demolition are presented in Table B-1 provided in **Appendix B**, included as an attachment to this report.

2.5.2 Technology Screening

The remedial technology screening was based on the following information/assumptions:

Assumptions Applicable to Decontamination and Demolition

- The technology needs to be effective for the removal or control of radiological contaminated building materials.
- On-site disposal was not considered feasible given that the Site is an active terminal facility overlying a shallow water table aquifer adjacent to the Delaware River. On-site disposal would not meet the RAOs since the material would be relocated on-site and the potential for human exposure would remain; therefore, ARARs and TBCs were not evaluated for on-site disposal options. In addition, based on the current and anticipated future use of the Site and its urban setting, it is likely that on-site disposal would require extensive pre-remediation requirements (*e.g.*, permitting, review/approvals by New Jersey and other Support Agencies), contaminated material segregation and testing requirements during remedial construction, and post-remediation cap and groundwater monitoring, as well as operation and maintenance (O&M) requirements.

Decontamination-Specific Assumptions

- The radiological contamination requiring remediation to achieve the PRG is limited to superficial building surfaces (1/8 inch), with the exception of one area in Room 11 (to a depth of 1-1/8 inches).
- The volume of material requiring disposal was estimated at 90 cy; all of this material was assumed to be Unimportant Quantities of Source Material (UQSM) – Resource Conservation and Recovery Act (RCRA) due to the presence of LBP in the building.
- Transportation and off-site disposal was included as a secondary technology. It was assumed that radiological wastes would be transported to the U.S. Ecology Facility in Boise, Idaho.

Demolition-Specific Assumptions

- The volume of material requiring disposal was estimated at 19,500 cy; 3.900 cy of UQSM and 15,600 cy of non-radioactively contaminated material. The non-radioactively contaminated material would be disposed of in a Subtitle D Landfill.
- Transportation and off-site disposal was included as a secondary technology. It was assumed that UQSM would be transported to the U.S. Ecology Facility in Boise, Idaho while non-radioactive waste would be transported to a Subtitle D Landfill in Pennsylvania.

A summary of the alternatives retained for detailed evaluation in this FS is given in **Table 2-4**. Based on the preliminary screening, the Institutional/Engineered Control general response action was not carried through this FS due to the following:

- Its limited long-term effectiveness and permanence since contamination is not removed.
- Contaminated building materials could become exposed in the future due to routine failure and could be mobilized during a catastrophic failure.
- The extensive O&M required for future use.
- Potential issues with State and community acceptance.

As both demolition and decontamination technologies achieve the same results regarding protectiveness of human health and the environment, complying with ARARs, and the short and long-term effectiveness of the remedies, all other general response actions were carried through the FS.

Table 2-4
Alternatives Retained for Detailed Screening

General Response Action	Effectiveness	Implementability	Cost	Other Considerations
No Action	Does not achieve RAO	Implementable	Capital: None O&M: None	None
Building Decontamination	Achieves RAO	Implementable	Capital: Medium O&M: None	Requires Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) Final Status Survey (FSS) for free release.
Building Demolition	Achieves RAO	Implementable; although numerous logistical considerations as property is active cargo terminal with significant truck traffic	Capital: High O&M: None	Requires radiological surveys during demolition for segregation of radiological/non-radiological materials, if appropriate.

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3 DEVELOPMENT AND SCREENING OF ALTERNATIVES

In accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988 OSWER Directive No. 9355.3-01), remedial alternatives were assembled by combining remedial technologies for removing surficial radiological contamination from building surfaces, and disposing of wastes in an off-site landfill. The purpose of the alternative development and screening process is to develop a range of possible remedial options that will achieve the RAOs identified for the Site. The following sections describe the development of remedial alternatives for the Armstrong Building.

3.1 RATIONALE FOR DEVELOPING ALTERNATIVES AND ALTERNATIVE DESCRIPTIONS

To streamline the RI/FS process, EPA has developed a well-defined decision making process used to accelerate selection of remedial actions at waste sites (called presumptive remedies). However, presumptive remedies are not applicable to this OU due to the media (building) and nature of the contamination (radionuclides). Therefore, proven industry-standards were used to develop remedial alternatives. The development of remedial alternatives for the Armstrong Building involved combining several of the technologies screened in Section 2. It should be noted that an alternative that combines partial decontamination with demolition was not considered since both decontamination and demolition alone meet the RAOs.

Alternative	Corrective Action	Alternative Description
1	None	No Action
2	Complete Decontamination	• Physical and/or chemical decontamination of Rooms 9, 10, 11, 13, 15, 17, 21, and Area A • FSS • Transport of UQSM or UQSM-RCRA waste to licensed/permitted facility • Reuse of Building
3	Complete Demolition	• Demolition of Building • On-site survey and segregation of radioactive and non-radioactive material • Transport of UQSM waste to licensed and permitted facility • Transport of non-radioactive materials to Subtitle D Landfill

3.1.1 Alternative 1 – No Action

Under CERCLA, a “No Action” alternative is typically evaluated to provide a common basis on which to evaluate the other alternatives. In this alternative, the Armstrong

Building would remain in its current condition without any provision for decontamination or engineering and ICs. Because the radiological contamination would remain in the building, the EPA would be required to conduct reviews of the building every five years. If contaminated portions of the building are used, then periodic inspections and exposure monitoring would also be required.

3.1.2 Alternative 2 - Complete Decontamination (Physical and/or Chemical), Off-site Disposal

Physical decontamination is the removal of surface radiological contamination by either surface cleaning or surface removal techniques while chemical decontamination is the removal of contamination through chemical reactions including acid or alkaline dissolution, redox reactions, and chelation (complexation, sequestration). Locations in Rooms 9, 10, 11, 13, 15, 17, 21, and Area A with radioactive levels above the PRG will be decontaminated to the required depth using a combination of physical and chemical decontamination techniques.

Selection of Decontamination Technique – In the Remedial Design, a combination of different physical and chemical decontamination methods will be evaluated for contaminated building surfaces. Chemical decontamination may be utilized on building surfaces which are non-porous, and free of paint, tiles and mastic. Chemical decontamination is not effective on porous, painted, or glazed surfaces, and may mobilize radiological or other contaminants when used for these media. Therefore, given the condition and construction of the buildings (brick and mortar walls from the turn of the last century, and painted surfaces on walls and concrete columns) chemical decontamination, if used, would only be effective on the concrete floors. Physical decontamination methods would be effective on the concrete floors, walls, and columns.

Site Preparation – is required for this alternative and includes the following.

- Mobilization of remedial contractor's personnel, equipment, and materials.
- Building preparation activities such as removal of debris, including soil and accumulated bird droppings and removal of investigation-derived waste (IDW) generated during the supplementary RI field work.
- Surface preparation including removal of floor and wall coverings that will not be effectively removed by the selected physical and/or chemical decontamination method(s), including common construction materials (*e.g.*, wallboard, lumber, plywood, Styrofoam, plastic sheeting) as well as potential ACM (*e.g.*, tiles and mastic). These common construction materials are assumed to be non-hazardous and sufficiently free of radiological contamination that they may be disposed of in a local landfill as construction debris or ACM in accordance with the ARARs and TBCs. Surface preparation will only occur for areas that will undergo chemical or physical decontamination.

- Prior to commencing radiological decontamination activities, the target surfaces for decontamination would be marked out in a one hundred square meter grid to allow for pre- and post-remediation scans and control of the remediation (*i.e.*, depth of penetration, 'hot spot' identification).

Decontamination – Either physical or a combination of physical and chemical decontamination methods could be used. Chemical decontamination activities may be utilized on floors which are non-porous, and free of paint, tiles and mastic while physical decontamination methods could be used for all surfaces. For physical decontamination, different methods would likely be used for walls and columns (*e.g.*, blasting with dust control skirts and vacuum filtration systems) and floors (*e.g.*, scarifier machine with vacuum shroud). Physical decontamination activities would commence on the walls and columns to prevent re-deposition of any removed materials or fugitive dusts on to the floor.

Post-Decontamination Activities – would include conducting surface scans to verify the cleanup goals were achieved. If 'hot spot' grids require additional surface removal to achieve the cleanup goals, decontamination would continue in incremental layers until surface scans indicate that decontamination appears to be complete and the MARSSIM FSS may be conducted.

Post-Cleanup Activities – After decontamination is complete, MARSSIM FSS surveys would be required for each established survey unit to free release the building for unrestricted use. Demobilization of remedial contractor's personnel, equipment, and materials, and removal of any waste materials, would also be required.

Decontamination Wastes:

- Physical decontamination wastes would vary depending on the method(s) utilized, could include concrete, brick and mortar dusts, and mixtures, as well as spent media (*e.g.*, grit, sand, shot). These wastes would be collected in drums and/or roll-off dumpsters, sampled for radiological contaminants and TCLP parameters, and, based on the analytical results segregated into UQSM or UQSM-RCRA waste, and shipped off-site to a licensed and permitted disposal facility. Additional waste streams include personal protective equipment (PPE), high efficiency particulate air (HEPA) filters, and other materials used during the decontamination process (*e.g.*, damp rags, brushes, plastic matting). These materials would be bulked in their respective waste streams and disposed during the remediation activities.
- Chemical decontamination wastes vary depending on the method(s) utilized but generally include liquid mixtures containing reagents and removed contaminants. Liquid chemical wastes typically require stabilization/solidification (*e.g.*, addition of Portland cement, lime, sand or other materials or chemicals) prior to transportation, as well as to satisfy disposal facility requirements. These wastes would be would be collected in drums and/or roll-off dumpsters, sampled for

radiological contaminants and TCLP parameters, and, based on the analytical results segregated into UQSM or UQSM-RCRA waste, and shipped off-site to a licensed and permitted disposal facility.

3.1.3 Alternative 3 - Complete Demolition, Off-site Disposal

Demolition is the tearing down of buildings by sawing, air hammer, explosives, shearing, tripping, or using heavy construction equipment (*e.g.*, excavator or a crane with a wrecking ball). Demolition is a proven technology for the removal of radiological contamination from the surfaces of facilities and equipment and may include the use of explosives, tripping, shearing, air hammering, and/or hydraulic excavators, wrecking balls, a combination of these, or other means that are appropriate. Demolition of radiologically contaminated buildings requires use of containment and monitoring measures to prevent migration of fugitive dust. Demolition includes preparing the demolished material for shipping and disposal, which may include segregation, size reduction, and screening of demolition rubble to reduce the volume of waste requiring disposal as UQSM. Given the condition and construction of the Armstrong Building (brick and mortar walls from the turn of the last century) and painted surfaces on walls and concrete columns, comprehensive lead based paint and asbestos surveys and structural/demolition assessment would be required to accurately estimate demolition material quantities, waste streams, and demolition methods for the remedial design and construction.

<u>Site Preparation</u> – is required for this alternative and includes the following.

- Mobilization of remedial contractor's personnel, equipment, and materials.
- Disconnection of utilities
- Removal of resident wildlife
- Coordination with the property owner/operator since this building is located on an active port.
- Construction of temporary haul roads, ingress/egress routes, decontamination facilities, and waste storage and processing area(s) on the port property.
- Building preparation activities such as removal of IDW generated during the supplementary RI field work (*e.g.*, disposing of drums or bulking radiological contaminated and non-hazardous materials in rolloff dumpsters).
- Asbestos abatement for entire building

<u>Demolition</u> – includes removal of above-grade building foundation and superstructure including floors, walls, and roofs, excluding substructures or basements. Demolition activities would be conducted to minimize cross contamination of demolition rubble and sequenced to prevent re-deposition while removing and handling materials.

Post-Demolition Activities – would include filling open basements and re-grading the area.

Demolition Wastes - would include rubble (concrete, reinforced concrete, brick and mortar), structural steel, lumber and plywood, miscellaneous construction debris (*e.g.*, Styrofoam), and HVAC equipment and ductwork.

Based on their origin and known or suspected contamination, these wastes would be stockpiled in a waste storage and processing area or collected in roll-off dumpsters for screening and/or size reduction, and segregation, sampled for radiological contaminants and TCLP parameters, and, based on the analytical results segregated into UQSM or UQSM-RCRA waste[9], and shipped off-site to a licensed and permitted disposal facility. Screening and size reduction equipment (*e.g.*, shakers, screeners, hammer mills equipped with conveyors) would be required to segregate non-radiological contaminated waste materials from the UQSM and UQSM-RCRA waste streams, if applicable.

Additional waste streams include PPE and other materials used during the demolition construction project. These materials would be bulked in their respective waste streams and disposed during the remediation activities.

Post-Cleanup Activities – Restoration includes backfilling substructures and removing temporary construction facilities and structures (ingress/egress routes, haul roads, waste storage and processing area). After restoration is complete, demobilization of remedial contractor's personnel, equipment, and materials, and removal of any waste materials, would be required.

3.2 SCREENING EVALUATION OF ALTERNATIVES

As discussed in Section 2.4, the initial general response actions were screened against several criteria including effectiveness, implementability, and, to a limited degree, cost to determine what alternatives should be retained for a more detailed screening. The alternatives retained for a more detailed screening are screened against these criteria again to reduce the number of alternatives that may undergo a more thorough and extensive analysis in Section 4. Therefore, alternatives will be evaluated more generally in this section than in the detailed analysis.

Effectiveness

Effectiveness relates to the ability of the remedial alternative to satisfy five evaluation criteria:

- Overall protection of human health and the environment (meets RAOs).
- Compliance with ARARs.

[9] For this FS it was assumed that none of the demolition debris would be classified as UQSM-RCRA.

- Short-term effectiveness (during remedial construction) and immediately after implementation of the remedy.
- Long-term effectiveness and permanence (following remedial construction).
- Reduction of toxicity, mobility, or volume through treatment

Effectiveness of each alternative is judged as follows:

- High: The alternative is effective in meeting all of the above criteria.
- Moderate: The alternative is effective in the overall protection of human health and the environment and compliance with ARARS, but one or more of the remaining three criteria are not met.
- Low: The alternative is not protective of human health and the environment.

The effectiveness evaluation is based on estimated cleanup times determined from experience with similar projects and discussions with remedial contractors.

Implementability

Implementability relates to the technical and administrative feasibility of constructing, operating, and maintaining the alternative. Technical feasibility relates to the practical aspects of construction, operation, and maintenance. Administrative feasibility relates to the ability to obtain permits; procure treatment, storage, and disposal services; and procure the needed land, equipment, and expertise.

Technologies have been previously screened in Section 2 and impractical/infeasible technologies eliminated (containment – engineered controls/ICs). Implementability of the alternatives is therefore judged solely as follows:

- High: The alternative is readily implemented and relies on proven technologies. Administrative elements are standard to the jurisdictional agencies.

- Moderate: The alternative is implementable and relies largely on proven technologies. Use of less available or innovative technology or more study may be required. Some administrative elements are not standard to jurisdictional agencies.

- Low: The alternative relies on less available or innovative technology or more study may be required. Many administrative elements are not standard to jurisdictional agencies.

Cost

The approximate present worth cost for each of the alternatives was estimated in this FS. The cost of each alternative is judged as follows:

- High: Over 10 million
- Moderate: Between 1 million to 10 million
- Low: Under 1 million

A detailed description of the evaluation of each alternative is presented in the following subsections, and is summarized in **Table 3-1**.

3.2.1 Alternative 1 – No Action

Effectiveness

Low. This alternative does not provide any reduction in contaminant concentrations or protection of human health and the environment. Lack of removal of the radiological contaminants is not protective of human health since the radiation and radiologically contaminated materials are not removed from the human health exposure pathway. Therefore, this alternative does not meet ARARs.

Implementability

High. No activities would be conducted under this alternative.

Cost

Low. The only costs are incurred are related to performing 5-year reviews.

Screening Result

This alternative is retained for detailed evaluation as it provides a basis for comparison as required by the NCP.

3.2.2 Alternative 2 – Complete Decontamination (Physical and/or Chemical), Off-site Disposal

Effectiveness

High. Since Alternative 2 will remove radioactively contaminated waste from the building, it is protective of human health and the environment and meets ARAR requirements. Alternative 2 is highly effective in the short term since the removal and disposal of the building surfaces will provide an immediate benefit to human health by eliminating the radiation exposure and inhalation pathway for contaminated dust. In addition, Alternative 2 poses little risk to site workers or the community during construction activities with proper implementation of site remediation controls and air monitoring measures. The components of this alternative may be completed simultaneously, reducing the time required for completion of the remedy. Therefore, Alternative 2 is highly effective for the long-term restoration of the Armstrong Building.

Implementability

High. Decontamination and disposal utilize proven technology which may be easily implemented at the Armstrong Building. Decontamination utilizes standard construction equipment (generators, compressors, tanks, and scissor lifts) making it easy to implement at the site. No ICs are required (*i.e.*, limiting site access due to residual contamination in the building, capping to prevent direct contact with on-site burial, or potential leaching to shallow groundwater).

Cost

Moderate. The present worth cost of removal, transportation and disposal is anticipated to be greater than 1 million dollars and less than 10 million dollars.

Screening Result

This alternative is retained for detailed evaluation as it meets the PRG and ARAR requirements.

3.2.3 Alternative 3 – Complete Demolition, Off-site Disposal

Effectiveness

High. Since Alternative 3 will remove radioactively contaminated waste from the property through removal of the building, it is protective of human health and the environment and meets ARAR requirements. Alternative 3 is highly effective in the short term since the removal and disposal of the buildings will provide an immediate benefit to human health by eliminating the radiation exposure and inhalation pathway for contaminated dust. In addition, Alternative 3 poses little risk to site workers or the community during construction activities with proper implementation of site remediation controls and air monitoring measures. The components of this alternative may be completed simultaneously, reducing the time required for completion of the remedy. Therefore, Alternative 3 is highly effective for the long-term restoration of the Armstrong Building.

Implementability

Low. Demolition itself is a proven technology that is easy to implement and utilizes standard construction equipment (excavators, wrecking balls). However, site access restrictions for and logistical considerations for staging, handling, storing, processing, loading and hauling waste materials will make implementation difficult. No ICs are required (*i.e.*, limiting site access due to residual contamination in the building, capping to prevent direct contact with on-site burial, or potential leaching to shallow groundwater).

Cost

High. The present worth cost of removal, transportation and disposal is anticipated to be greater than 10 million dollars.

Screening Result

This alternative is retained for detailed evaluation as it meets the PRG and satisfies the ARARs.

Table 3-1
Alternatives Retained for Detailed Evaluation

General Response Action	Effectiveness	Implementability	Cost	Retained
No Action	Low	High	Low	Retained to provide basis of comparison for other alternatives
Building Decontamination	High	High	Moderate	Retained
Building Demolition	High	Moderate	High	Retained

4 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

In accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988 OSWER Directive No. 9355.3-01), remedial alternatives for the Armstrong Building were assessed against the nine evaluation criteria in 40 CFR 300, §300.430(e)(7)(iii), including:

- Overall protection of human health and the environment.
- Compliance with ARARs.
- Long-term effectiveness.
- Reduction of toxicity, mobility, or volume through treatment.
- Short-term effectiveness.
- Implementability.
- Cost.
- State (and/or Support Agency) acceptance.
- Community acceptance.

Under the NCP, the selection of a remedy is based on these criteria, which are categorized into three groups:

- <u>Threshold Criteria</u> - must be satisfied in order for an alternative to be eligible for selection. The threshold criteria are overall protection of human health and the environment and compliance with ARARs.
- <u>Primary Balancing Criteria</u> - are used to weigh the relative merits of alternatives and include long-term effectiveness and permanence, the reduction of toxicity, mobility, or volume through treatment, short-term effectiveness, implementability, and cost.
- <u>Modifying Criteria</u> – include State acceptance and community acceptance and they must be considered during remedy selection.

A description of the nine criteria, as well as a summary of the evaluation of the selected remedial alternatives against these criteria, is provided in the following sections and summarized in **Table 4-1**.

4.1 Description of Evaluation Criteria

4.1.1 Overall Protection of Human Health and the Environment

The assessment against this criterion describes how each alternative, as a whole, achieves and maintains protection of human health and the environment. The overall assessment of protection draws on the assessments conducted previously and compliance with ARARs. Evaluation of the overall protectiveness of an alternative during the RI/FS should focus on whether a specific alternative achieves adequate protection and should describe how site risks posed through each pathway being addressed by the FS are eliminated, reduced, or controlled through treatment, engineering, or ICs. This evaluation also allows for consideration of whether an alternative poses any unacceptable short-term or cross-media impacts.

4.1.2 Compliance with ARARs

The assessment against this criterion describes how the alternative complies with ARARs, and, as appropriate, TBCs. This evaluation criterion is used to determine whether each alternative will meet the Federal and State ARARs identified in previous stages of the RI/FS process.

4.1.3 Long-Term Effectiveness

The assessment of alternatives against this criterion evaluates the long-term effectiveness of alternatives in maintaining protection of human health and the environment after response objectives have been met. The following components of the criterion should be addressed for each alternative:

- Magnitude or Residual Risk – This factor assesses the residual risk remaining from untreated waste or treatment residuals at the conclusion of remedial activities, (*e.g.*, after source containment and/or treatment are complete).
- Adequacy and Reliability of Controls – This factor assess the adequacy and suitability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain at the site. This factor is not applicable to any of the remedial alternatives developed for the Armstrong Building.

4.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The assessment against this criterion evaluates the anticipated performance of the specific treatment technologies an alternative may employ. This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal element. In evaluating this criterion, an assessment should be made as to whether treatment is used to reduce principal threats, including the extent to which toxicity, mobility, or volumes are reduced either alone or in combination.

4.1.5 Short-term Effectiveness

The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy until response objectives have been met. Under this criterion, alternatives should be evaluated with respect to their effects on human health during implementation of the remedial action. The following factors should be addressed as appropriate for each alternative: protection of the community during remedial actions; protection of workers during remedial actions; environmental impacts; time until remedial response objectives are achieved.

4.1.6 Implementability

This assessment evaluates the technical and administrative feasibility of alternatives and the availability of required goods and services. This criterion involves analysis of technical feasibility, administrative feasibility, and availability of services and materials. Potential implementation problems may be overcome by selecting the appropriate method for a given building surface and conducting bench and/or field scale treatability testing, as well as collecting representative samples and profiling the waste as part of the remedial design process. Both physical and chemical decontamination technologies can be performed without any significant administrative requirements.

4.1.7 Cost

This assessment evaluates the capital and O&M costs of each alternative.

- Capital Costs - Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs. Direct costs include expenditures for the equipment, labor, and materials necessary to install remedial actions. Indirect costs include expenditures for engineering, financial, and other services that are not part of actual installation activities but are required to complete the installation of remedial alternatives. Costs that must be incurred in the future as part of the remedial action alternative should be identified and noted for the year in which they will occur.
- Annual O&M Costs - Annual O&M costs are post-construction costs necessary to ensure the continued effectiveness of a remedial action.

4.1.8 State (and/or Support Agency) Acceptance

This assessment reflects the state's (or support agency's) apparent preferences among or concerns about alternatives. NJDEP has provided input during the RI phase and will continue to provide input through the FS and public comment period.

4.1.9 Community Acceptance

This assessment reflects the community's apparent preferences among or concerns about alternatives. As with state acceptance, this criterion will be addressed in the Record of Decision (ROD) once comments on the RI/FS Report and Proposed Plan have been received.

4.2 Individual Analysis of Alternatives

Detailed evaluations of the remedial alternatives retained for further evaluation in Section 3.0 are presented in this section and Section 4.3. Cost estimates for the remedial alternatives were prepared using the Remedial Action Cost Engineering and Requirements system (RACER), release version 10.3. RACER is a parametric cost modeling system that was developed through a combination of private and Federal Government (*i.e.*, Air Force, US Army, USDOE, EPA) funding. The RACER cost technologies are based on generic engineering solutions derived from historical project information, industry data, government laboratories, construction management agencies, vendors, contractors, and engineering analysis. RACER includes contractor costs with profit, owner costs, contingency and markups including a location modifier of 1.214 for Camden, NJ. The RACER estimates are conservative costs within -30% to +50% range of anticipated remediation costs and therefore are suitable for evaluating remedial alternatives, in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988 OSWER Directive No. 9355.3-01).

It should be noted that a significant amount of Site-specific cost information is available for the Welsbach/General Gas Mantle Site, based on ongoing remedial activities at OU1. Therefore, where appropriate, generic costs in the RACER model were replaced with Site-specific costs. In addition, technology, vendor, and contractor estimates were also used to verify or supplant RACER estimates, where appropriate. A summary of the Site-specific costs used in RACER are described below while the RACER estimate documentation reports and contractor price quotes are included in **Appendix B**. The input parameters including contaminated building material quantities and supporting documentation, are described for each Alternative in Section 4.3. The use of RACER estimates or supporting cost information for the components of the remedial alternatives (*i.e.*, decontamination, off-site transportation and disposal, FSS) is described in the following sections, as well as Section 4.3.

4.2.1 Alternative 1 – No Action

Alternative 1 consists of no remedial action to remove, treat and/or dispose of the contaminated building materials. The purpose of providing a no action alternative is to provide a baseline against which the other remedial alternatives can be compared.

<u>Overall Protection of Human Health and the Environment</u>

The No Action Alternative is not protective of human health since the contamination would be left in place and the potential would remain for human exposure through a catastrophic release, during demolition of the building, and/or if the entire building were to be re-used.

<u>Compliance with ARARs</u>

The No Action Alternative does not comply with the ARARs in Section 2.1.

Long-term Effectiveness

The No Action Alternative does not offer long-term effectiveness as radioactive contamination would remain on-Site and the current level of risk would remain.

Reduction of Toxicity, Mobility, or Volume Through Treatment

The No Action Alternative does not reduce the toxicity, mobility, or volume of radiological contamination.

Short-term Effectiveness

The No Action Alternative does not offer short-term effectiveness and the current level of risk would remain.

Implementability

Since no response actions would be conducted, the No Action Alternative is readily implementable.

Cost

The only costs associated with this alternative would be for conducting a five-year review. Costs for the five-year review were not included in this FS.

State (and/or Support Agency) Acceptance

It is anticipated that the No Action Alternative would not be acceptable to the NJDEP since contamination resulting in incremental cancer risks greater than the upper end of the risk range would remain in place.

Community Acceptance

It is anticipated that the No Action Alternative would not be acceptable to the community since contamination resulting in incremental cancer risks greater than the upper end of the risk range would remain in place.

4.2.2 Alternative 2 – Complete Decontamination (Physical and/or Chemical Decontamination), Off-Site Disposal

Overall Protection of Human Health and the Environment

Alternative 2 is protective of human health since the radioactive contamination would be removed from the building and disposed of at an off-site landfill that is permitted to accept radiological waste.

Compliance with ARARs

Alternative 2 complies with the ARARs since radiological contamination would be removed to meet the PRG for the Site. As a result, there would be no unacceptable risks to human health and the environment.

Long-term Effectiveness

Alternative 2 offers long-term effectiveness and permanence for the general public, workers and future tenants/residents since radiological contamination would be removed to meet the PRG for the Site, and the excavated material would be sent off-site for disposal at an approved off-site licensed facility.

Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2 does not reduce toxicity or volume of radiological contamination through treatment. The potential mobility of radiological contamination will be reduced with successful decontamination, transportation, and off-site disposal. However, the potential for increased toxicity exists during chemical decontamination when the radiological contamination is concentrated, or mixed with other wastes. The potential for mobilizing radiological contamination exists for decontamination via dust migration or accidental spills/releases, even though it is unlikely with proper implementation and controls. The potential also exists for increasing the volume of radiological contaminated materials by introducing physical media or chemical solutions.

Short-term Effectiveness

The overall remediation implementation period is estimated to be one year; however, the actual field remediation of floors and walls is limited to approximately 8-12 weeks. There are potential risks to remediation workers and residents associated with Alternative 2. However, with proper implementation of engineering controls (*e.g.*, dust control) and material and waste handling procedures, decontamination is effective in protecting human health and the environment during construction.

Implementability

Alternative 2 utilizes readily available, proven technologies for conducting and monitoring the remediation effectiveness. Potential issues include:

- Selecting an appropriate physical decontamination technique or formulating a Site-specific chemical treatment.
- Waste classification and disposal facility approvals since wastes generated from radiological decontamination may include solid and/or liquid wastes that require stabilization/solidification prior to transportation, as well as to satisfy disposal facility requirements. Wastes generated from decontamination may also include UQSM-RCRA waste due to LBP.

Cost

The cost for Alternative 2 is 3.5 million. As described in Section 4.2, the costs include remedial contractor costs for personnel, equipment and materials including profit, FSS, waste transportation and off-site disposal costs, as well as owner costs for engineering, project management and construction oversight, and 50% contingency. Due to the one year implementation period, and since complete decontamination of the building is proposed, no annual O&M Costs would be incurred.

For Alternative 2, the following assumptions were used to develop the cost estimate:

- The quantity of radioactively contaminated building surfaces is estimated to be 90 cy. The remediation material quantity estimates are presented in **Table 2-3**, and the basis and assumptions are described in Section 2.5.1.2.3.
- It was assumed that radiological wastes would be transported to the U.S. Ecology Facility in Boise, Idaho and disposed as either UQSM or UQSM-RCRA, consistent with transportation and off-site disposal of contaminated soil and construction debris for OU1. For this FS, the decontamination wastes were assumed to be UQSM-RCRA to provide the most conservative cost estimate for disposal and since the possibility exists for cross-contamination from lead paint on the walls to the floors. Recent transportation and disposal costs for material shipped from the Site for OU1 as UQSM-RCRA are approximately $116/ton for transportation per gondola rail car shipment and $110/cy for disposal[10]. These rates were used in the RACER cost estimate to approximate a total cost for transportation and disposal of $67,000, including markups and 50% contingency, waste evaluation fees, loading and transporting the waste, and disposal fees.
- ACM Abatement - An additional cost of $300,000 for ACM characterization, abatement and disposal, assuming 25% of floor surfaces contain ACM tiles and mastic, including 50% contingency, 20% owner costs and markup, were assumed based on the contractor cost estimate provided in **Appendix B**.
- FSS - The total cost for the FSS from the RACER estimate is 1.8 million which includes remedial contractor costs and profit, markups, owner costs (*e.g.*, engineering and design, construction oversight, reporting, project management) and 50% contingency. For comparison, cost estimates for conducting an FSS were obtained from a contractor (see **Appendix B**) and were approximately

[10] The majority of building material (approximately 75%) is reinforced concrete with rebar, while the remainder is brick and glass, structural steel, roofing, wood, and HVAC equipment/ductwork. Portland cement is approximately 148 pounds per cubic foot, which is equivalent to approximately 2 tons per cy. Given the building age and likelihood of significant rebar content in concrete materials, this unit weight was increased by 10% to 2.2 tons/cy. It is noted that building demolition rubble will be reduced to approximate 6-inch nominal diameter or less and bulked for scanning prior to load out to minimize the amount of void space in the shipments (minimizing cost) as well as satisfy transportation hauler and disposal facility requirements. Therefore, 2.2 tons/cy was used as a reasonable and conservative estimate for estimating material quantities and remediation costs."

$27,000 per room per survey (100 m^2 per survey). Using the surface areas in IEM's FS yields approximately 32 FSS surveys (100 m^2 each) for the eight rooms, for a total of approximately $864,000. A total of eight remediation support surveys were also assumed for each of the eight rooms (for intermediate or additional final scans) at a cost of $11,000 per survey, for a total of approximately $88,000. The contractor also estimates mobilization and demobilization costs of $20,000 for a direct cost total of $972,000. Adding an equivalent markup of 20% for owner costs, and a 50% contingency to those used for RACER brings the adjusted total for the FSS using the contractor estimate to approximately 1.8 million. Therefore, the adjusted contractor cost estimate was retained for the remedial alternative cost evaluation/comparison since it is more conservative and still compares reasonably well with the RACER cost estimate.

State (and/or Support Agency) Acceptance.

It is anticipated that Alternative 2 would be acceptable to NJDEP since the remedy would reduce all concentrations in the building to below the PRG for the Site. In addition, the Alternative 2 complies with ARARs, offers short-term and long-term effectiveness and permanence, reduces the potential mobility of radiological contamination, is readily implementable, and cost-effective.

Community Acceptance.

It is anticipated that Alternative 2 would be acceptable to the community as the remedy would reduce all concentrations in the building to below the PRG for the Site.

4.2.3 Alternative 3 – Complete Demolition, Off-Site Disposal

Overall Protection of Human Health and the Environment

Alternative 3 is protective of human health since the radiological contamination would be removed from the building and disposed of at a permitted landfill.

Compliance with ARARs

Alternative 3 complies with the ARARs since radiological contamination would be removed to meet the PRG for the Site. As a result, there would be no unacceptable risks to human health and the environment.

Long-term Effectiveness

Alternative 3 offers long-term effectiveness and permanence for the general public, workers and future tenants/residents since radiological contamination would be removed to meet the PRG for the Site, and the excavated material would be sent off-site for disposal in a controlled, licensed facility.

Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 3 does not reduce toxicity or volume of radiological contamination through treatment. The potential mobility of radiological contamination will be reduced with successful demolition, transportation, and off-site disposal. There is a potential for mobilizing radiological contamination during demolition via dust migration or accidental spills/releases; however, with proper implementation and controls this risk would be reduced. The potential also exists for increasing the volume of radiological contaminated materials through the cross contamination of the waste with non-contaminated building rubble.

Short-term Effectiveness

The overall remediation implementation period is estimated to be less than two years; however, the actual demolition is limited to approximately six months. There are potential risks to remediation workers and residents associated with Alternative 3. However, with proper implementation of dust control, material, and waste handling procedures, Alternative 3 is effective in protecting human health and the environment during construction.

Implementability

Alternative 3 utilizes readily available, proven technologies for conducting and monitoring the remediation effectiveness. Potential issues include:

- Coordination with the property owner/operator since this building is located on an active port.
- There are significant site access issues for staging, handling, storing, processing, loading and hauling waste materials which will make implementation very difficult for the Site including:
    - A large area would be required for staging and processing waste materials.
    - Haul roads and ingress/egress routes would be difficult to construct and operate with frequent truck traffic on the active port facility.
- A large volume of waste would require off-site disposal as both construction debris and UQSM.
- Waste classification and disposal facility approvals may be necessary since wastes generated from demolition may include UQSM-RCRA waste.

Cost

The cost for Alternative 3 is 103 million. As described in Section 4.2, the costs include remedial contractor costs for personnel, equipment and materials including profit, waste transportation and off-site disposal costs, as well as costs for engineering, project management, construction oversight, and a 50% contingency. Due to the one year implementation period, and since complete demolition is proposed, no annual O&M Costs would be incurred for the Alternative 3.

For Demolition Alternative 3, the following was used in the cost estimate:

- The quantity of building rubble and construction debris is estimated to be 19,500 cy. This value includes approximately 15,200 cy of concrete (reinforced with rebar), 1,000 cy of brick and glass, and 3,300 cy of other building materials (*e.g.*, structural steel from roofs, piping, and HVAC equipment and ductwork). The demolition material quantity estimates are presented in Table B-1 provided in **Appendix B**.
- Transportation and Disposal Costs - It was assumed that 20% of wastes generated from demolition would be radiological wastes (*i.e.*, UQSM) and 80% would be non-hazardous for disposal in a Subtitle D Facility. Radiological wastes would be transported to the U.S. Ecology Facility in Boise, Idaho and disposed as UQSM while non-hazardous wastes would be transported to a local Subtitle D Landfill. Recent transportation and disposal costs for material shipped from the Site for OU1 as UQSM and non-hazardous wastes are as follows:
    - UQSM: approximately $116/ton for transportation per gondola rail car shipment and $84.50/cy for disposal.
    - Non-hazardous/Subtitle D: $18/ton for transportation via triaxial dump truck and $72/ton for disposal (disposal fee of $158/cy using a conversion of 2.2 ton/cy).

  These rates were used in the RACER cost estimate to approximate a total cost for transportation and disposal of 8.8 million including markups, waste evaluation fees, loading and transporting the waste, disposal fees, and 50% contingency.
- ACM Abatement - An additional cost of $900,000 for ACM abatement and disposal, assuming 25% of floor surfaces contain ACM tiles and mastic, with an additional 10% for other ACM encountered during demolition (*e.g.*, pipe insulation, window caulking), along with 50% contingency and 20% owner costs and markup, was assumed based on the contractor cost estimate provided in **Appendix B**.
- Material Segregation and Radiological Scans.

<u>State (and/or Support Agency) Acceptance.</u>

Demolition Alternative 3 complies with ARARs, offers short-term and long-term effectiveness and permanence, reduces the potential mobility of radiological contamination, is readily implementable, and cost-effective. While Alternative 3 would satisfy the RAOs, this alternative may not be acceptable to NJDEP due to the high remedial action cost.

Community Acceptance.

It is anticipated that Alternative 3 would be acceptable to the community as the remedy would remove the building and associated radiological contamination.

4.3 Comparative Analysis of Alternatives

As part of the detailed analyses of alternatives, comparisons of the selected alternatives (*i.e.*, those that passed the initial screening), were made to identify differences between the alternatives and how site risks are addressed. The alternatives are compared with respect to each other regarding each of the nine NCP evaluation criteria, and any differences are identified. **Table 4-1** presents a summary of the evaluations for Alternatives 1, 2, and 3.

Overall Protection of Human Health and the Environment

Alternatives 2 and 3 would provide overall protection of human health and the environment on a similar basis or level. Alternative 1 would not achieve this criterion since radioactive contamination associated with the Site would not be removed.

Compliance with ARARs

Alternatives 2 and 3 would comply with applicable or relevant ARARs. Alternative 1 would not achieve this criterion since radioactive contamination associated with the Site would not be removed.

Long-Term Effectiveness and Permanence

Alternatives 2 and 3 offer long-term protection of human health and the environment as both remedial actions would be permanent, and all contaminated building materials would be removed from the site for disposal in an off-site controlled, licensed facility. Alternative 1 would not achieve this criterion.

Reduction of Toxicity, Mobility, or Volume Through Treatment

There would be no reduction of toxicity, mobility, or volume through treatment for Alternatives 1, 2, 3. No treatment technology presently exists that will reduce the toxicity, mobility or volume of radium and thorium. However, Alternatives 2 and 3 would reduce the mobility of radiological contaminants by removal, off-site disposal, and management of these wastes at an approved landfill permitted to accept radiological waste.

Short-Term Effectiveness

Exposure to radiological contamination by construction workers and the public during implementation of Alternatives 2 and 3 is a potential concern. However, exposure to radiological contamination would be limited by the use of: on-site engineering control measures for minimizing dust generation; restrictions on the size of area being worked; and other demolition best management practices that would minimize the exposure to particulate contaminants. Alternative 1 would not achieve this criterion since radiological contamination and the associated risks would remain.

Implementability

Alternative 1 would be the most easily implemented as no additional actions would be taken. Both Alternatives 2 and 3 are implementable as experienced firms, personnel, and equipment are readily available. With Alternative 2, only a limited area would be needed for access and staging requirements. While Alternative 3 utilizes readily available, proven technologies for conducting and monitoring the remediation effectiveness, from a logistical standpoint, this alternative would be difficult to implement. The Armstrong Building is located on a very active port, warehouse, and logistics facility, and significant access restrictions would be present due to the limited space for storing and handling wastes on-site and the significant coordination with port operators. Alternative 3 will also generate a significant volume of both construction debris and radiologically contaminated waste for disposal.

Costs

The costs associated with each alternative are provided in **Table 4-1**. Alternative 1 is the least expensive alternative to implement. Alternative 3 would be significantly more expensive to implement than Alternative 2 due to complete demolition costs and transportation and off-site disposal costs for the large quantities of UQSM and non-hazardous wastes.

4.3.1 Summary

The critical evaluation criteria for the remedial alternatives are: the overall protection of human health and the environment, based on the mitigation of incremental lifetime cancer risks to workers and building resident receptors; the reduction of mobility of radiological contamination; implementability; and the short-term and long-term effectiveness.

Based on the evaluation of alternatives, decontamination of building was determined to be the most viable remedial alternative.

Table 4-1
Summary Evaluation of Remedial Alternatives

Criterion	Alternative 1 No Action	Alternative 2 Complete Decontamination and Off-Site Disposal	Alternative 3 Demolition and Off-Site Disposal
Overall Protection of Human Health and the Environment			
Prevent Human Exposure to Building Contaminants	Does not comply	Exposure would be eliminated through removal of radioactively contaminated materials	Exposure would be eliminated through removal of radioactively contaminated materials
Minimize Contaminant Migration	Does not comply	Migration would be eliminated through removal of radioactively contaminated materials	Migration would be eliminated through removal of radioactively contaminated materials
Compliance with ARARs			
Chemical-Specific	Does not comply	Complies	Complies
Location-Specific	None identified	None identified	None identified
Action-Specific	Not applicable	Complies	Complies
Long-Term Effectiveness and Permanence			
Magnitude of Residual Risk	Future risks would remain	Eliminates risks	Eliminates risks
Need for 5-Year Review	Yes	No	No
Reduction of Toxicity, Mobility, or Volume Through Treatment			
Reduction of Toxicity, Mobility, or Volume Through Treatment	No treatment is available for radium and thorium contamination	No treatment is available for radium and thorium contamination	No treatment is available for radium and thorium contamination
Short-Term Effectiveness			
Community Protection	Potential risk due to fire or building collapse	No significant risk due to use of engineering controls	No significant risk due to use of engineering controls
Worker Protection	Not applicable	Minimal risk due to use of engineering controls	Minimal risk due to use of engineering controls
Environmental Impacts	Potential risk due to fire or building collapse	No significant risk due to use of engineering controls	No significant risk due to use of engineering controls
Time to Implement	Not applicable	One Year	Two Years
Implementability			
Implementability	Easily implementable	Readily implementable	Difficult to implement
Cost			
Cost	None	3.5 million	103 million

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APPENDIX A

Technical Memorandum

A Comparison of RESRAD-Build with the Online EPA BPRG Calculator Tool for the Armstrong Building at the Welsbach/GGM Superfund Site

TECHNICAL MEMORANDUM

A Comparison of RESRAD-Build with the Online EPA BPRG Calculator Tool for the Armstrong Building at the Welsbach/GGM Superfund Site

US Army Corps of Engineers
Kansas City District
9 June 2011

TECHNICAL MEMORANDUM
A Comparison of RESRAD-Build with the Online EPA BPRG Calculator Tool for the Armstrong Building at the Welsbach/GGM Superfund Site
9 June 2011

EXCUTIVE SUMMARY

1. The US Army Corps of Engineers (USACE) prepared this Technical Memorandum (TM) in support of US Environmental Protection Agency (EPA) Region 2 and the Welsbach/GGM Superfund Project. Based on discussions herein USACE has determined that the Department of Energy (DOE) RESidual RADioactivity in BUILDings RESRAD-Build version 3.5 (DOE 2009) (developed by the Argonne National Laboratory) is an acceptable model to develop site specific criteria at the Armstrong Building of the Welsbach/GGM Superfund Project.

2. **Purpose:** The Purpose of this TM is to provide a comparison of RESRAD-Build (RESBLD) and the current online version of the EPA Preliminary Remediation Goals for Radionuclides in Buildings (BPRG) calculator (EPA 2009) (developed by the Oak Ridge National Laboratory). This TM also provides an estimate of reasonable Derived Concentration Guideline Levels (DCGL) potentially to be applied at the Armstrong Building of the Welsbach/GGM Superfund Project.

3. **Conclusions**

3.1 The RESRAD-Build Model and BPRG calculator compare favorably. The ability for RESRAD-BLD to better model future use scenarios and to be more site specific is an advantage to the Armstrong Building project team due to the amount of site specific data available from the Remedial Investigation (RI) and the recent supplemental RI.

3.2 The online BPRG calculator serves as a useful tool for a first estimate of screening levels at the Armstrong Building. The incorporation of site specific data into the BPRG calculator and then into RESRAD-Build has facilitated the evolution of initial generalized BPRG derived values into more accurate and site specific DCGLs ranges.

3.3 A better understanding of the BPRG calculator and how it handles complex decay chain calculation for future use scenarios is required before USACE can recommend use of the BPRG calculator to develop DCGLs for the Th-232 decay chain.

4. Recommendations

4.1 **Use** of the RESRAD-BLD code to develop DCGLs for the Armstrong Building at the Welsbach/GGM Superfund site is recommended due to the amount of available site specific data and the flexibility of the model.

4.2 Developed DCGLS should be well within the ranges of DCGLs presented in Table 5.

TECHNICAL MEMORANDUM

A Comparison of RESRAD-Build with the Online EPA BPRG Calculator Tool for the Armstrong Building at the Welsbach/GGM Superfund Site
9 June 2011

1. The US Army Corps of Engineers (USACE) prepared this Technical Memorandum (TM) in support of US Environmental Protection Agency (EPA) Region 2 and the Welsbach/GGM Superfund Project. Based on discussions herein USACE has determined that the Department of Energy (DOE) RESidual RADioactivity in BUILDings RESRAD-Build version 3.5 (DOE 2009) (developed by the Argonne National Laboratory) is an acceptable model to develop site specific criteria at the Armstrong Building of the Welsbach/GGM Superfund Project.

2. **Purpose:** The Purpose of this TM is to provide a comparison of RESRAD-Build (RESBLD) and the current online version of the EPA Preliminary Remediation Goals for Radionuclides in Buildings (BPRG) calculator (EPA 2009) (developed by the Oak Ridge National Laboratory). This TM also provides an estimate of reasonable Derived Concentration Guideline Levels (DCGL) potentially to be applied at the Armstrong Building of the Welsbach/GGM Superfund Project.

3. Discussions

3.1 <u>Background</u>

3.1.1 As part of the Baseline Risk Assessment (BRA) at the Armstrong Building, the computer code RESBLD was used to model interior contamination at the Armstrong Building to determine site specific risk levels and further in the draft Feasibility Study (FS) to develop site specific Derived Concentration Guideline Levels (DCGLs) for each contaminant of concern (COC). To further evaluate the appropriateness of derived DCGLs, the output of the site specific RESBLD model was compared to results from EPAs (BPRG) model via the online calculator tool.

3.1.2 RESRAD-Build version 3.5

USACE has used the RESRAD and RESRAD-Build computer codes at numerous Department of Defense (DOD), DOE, EPA, and Nuclear Regulatory Commission (NRC) sites and projects.

According to the RESBLD User's guide –

> *"….. the manual and code have been used widely by the U.S. Department of Energy and its contractors, the U.S. Nuclear Regulatory Commission, and many other government agencies and institutions."*

> *"The RESRAD-BUILD computer code is a pathway analysis model designed to evaluate the potential radiological dose incurred by an individual who works or lives in a building contaminated with radioactive material. The transport of radioactive material within the building from one compartment to another is calculated with an indoor air quality model. The air quality*

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model considers the transport of radioactive dust particulates and radon progeny due to air exchange, deposition and resuspension, and radioactive decay and ingrowth. A single run of the RESRAD-BUILD code can model a building with up to three compartments, four source geometries (point, line, area, and volume), 10 distinct source locations, and 10 receptor locations. The volume source can be composed of up to five layers of different materials, with each layer being homogeneous and isotropic. A shielding material can be specified between each source-receptor pair for external gamma dose calculations. The user can select shielding material from eight different material types. Seven exposure pathways are considered in the RESRAD-BUILD code: (1) external exposure directly from the source, (2) external exposure to materials deposited on the floor, (3) external exposure due to air submersion, (4) inhalation of airborne radioactive particulates, (5) inhalation of aerosol indoor radon progeny and tritiated water vapor, (6) inadvertent ingestion of radioactive material directly from the source, and (7) ingestion of materials deposited on the surfaces of the building compartments. Various exposure scenarios may be modeled with the RESRAD-BUILD code. These include, but are not limited to, office worker, renovation worker, decontamination worker, building visitor, and residency scenarios. Both deterministic and probabilistic dose analyses can be performed with RESRADBUILD, and the results can be shown in both text and graphic reports."

3.1.3 EPA BPRG Calculator

USACE has used the EPA BPRG calculator at a few sites and projects; however, to date our experience with it is less than that with RESRAD-Build.

According to the BPRG User's guide –

"This guidance document sets forth recommended approaches based upon the current available and relevant science with respect to risk assessment for response actions at CERCLA sites. This document does not establish binding rules. Alternative approaches for risk assessment may be found to be more appropriate at specific sites (e.g., where site circumstances do not match the underlying assumptions, conditions and models of the recommended guidance). The use of this recommended guidance or of alternate approaches in the consideration or selection of remedial or removal actions on CERCLA sites should be reflected in the Administrative Records for such sites."

"PRGs are risk-based, conservative screening values that can be used to identify areas and contaminants of potential concern (COPCs), and that either do or do not warrant further investigation. PRGs typically are tools for evaluating and cleaning up contaminated sites. They are not de facto *cleanup standards and should not be applied as such; however, they may be helpful in providing long-term targets to use during the analysis of remedial alternatives. In general, generic PRGs are used before site-specific risk assessments as a screening tool. After the baseline risk assessment, PRGs are typically refined to incorporate site-specific knowledge and conditions.*

This calculator is based on Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals) (RAGS Part B). RAGS Part B provides guidance on using EPA toxicity values and exposure information to calculate risk-based recommended BPRGs. Recommended for initial use at the scoping phase of a project using readily available information, risk-based recommended BPRGs generally are modified based on site-specific data gathered during the RI/FS study."

3.2 Comparisons

3.2.1 General Comparisons

The two models are based on similar guidance and information. In fact the BPRG manual states, "*Calculation of the recommended BPRGs are based on the risk assessment work (EPA 2003) for chemicals and RESRAD BUILD (Developed for the U.S. Department of Energy by Argonne National Laboratory) and the default inputs are based on Superfund parameters.*" Accordingly if the two models were used to model the exact same exposure scenario it is expected that the ultimate results would be similar.

A significant difference between the two models is that RESBLD can provide dose and risk modeling given a source exposure scenario where BPRG is designed to output a screening value given a target risk. By design BPRG does not consider radiation dose. Thus, the two models approach the same scenario differently. Stated differently, RESBLD with model input, including COC source concentration, provides an estimate of dose and risk while BPRG with model inputs, including target risk value, provides an acceptable COC concentration.

Another difference between the models is the application to current and future scenarios. BPRG is very effective at determining screening values for current occupancy scenarios (resident and worker) in three primary exposure paths/media (air, dusts, external). BPRG provides screening values for each separately while RESBLD combines the exposure from each to one value as well as reports path/media specific values that can be used to determine specific screening values.

For future use scenario criteria development the EPA BPRG approach assumes that significant source removable is unlikely and that portion that may become removable is subject to removal by cleaning (vacuuming, dusting, etc.) thus insignificant. Accordingly, for future use criteria, the BPRG external exposure model should be used. The BPRG calculator may not be suitable for determining DCGLS if the future removable fraction is likely to exceed that removed by cleaning. The amount of future removable contamination and the level and frequency of cleaning conducted in a future home or office adds significant uncertainty to the use of either model. RESRAD-Build is capable of modeling these factors in future use scenarios while BPRG is not.

Another difference between the models is flexibility and data requirements. RESBLD allows for many more site specific inputs than BPRG, thus it is a more flexible model. To take full advantage of this flexibility, significantly more site specific data is required. Alternatively, the BPRG calculator is designed to standardize the evaluation and cleanup of radioactively contaminated buildings for which risk is being assessed. BPRG requires zero to little site specific information. Examples of model input differences are included in Table 1.

Table 1. General Comparison of Models

	RESRAD-BLD	BPRG	Note
# Exposure Scenarios	5+ (any)	2 (resident, worker)	BPRG notes that other scenarios could be investigated by altering inputs
# Exposure Pathways	7	6	RESRAD BLD adds radon and tritiated water
Room size	Any	Choice of 5 sizes	RESRAD BLD can be set to match BPRG.
# Receptors	Up to 10	1	RESRAD BLD can be set to match BPRG.
# Receptor locations	Up to 10	4 choices	BPRG does have an average position
# of Sources	Up to 10	1	BPRG assumes all room surfaces contaminated
# of rooms	Up to 3	1	
Source inputs	Site specific (flexibility)	Standard, no input	BPRG considers hard and soft surfaces
Outputs	Dose or risk	Activity	Can use either to calculate the other

3.2.2 Specific Comparisons

While both models provide output for Ambient air it should be noted that the BPRG Ambient Air calculator was not evaluated as it provides a PRG value only for volumetric air concentrations and does not calculate a surface PRG. The RESBLD model evaluates the air concentrations inherently.

The BPRG model uses a direct ingestion settled dusts model to account for the direct ingestion of radionuclides, which is not the scenario at the Armstrong building. It is known that much of the contamination present is fixed contamination rather than contamination present as ingestible dust particulates. For the purpose of RESBLD modeling, 10% of the contamination was assumed to be removable with a life time of 100 years and modeled as indirect ingestion of dust. As such, the BPRG dust model will likely over estimate risk from internal deposition of surface contamination by determining a value for contamination based on an assumption that 100% of the contamination is available for direct ingestion.

Conversely, the BPRG external model derives PRG values based solely on external exposure from radionuclide contamination without taking into consideration internal deposition from inhalation or ingestion and as such may under estimate the dose from alpha and beta emitting radionuclides such as those present in the Armstrong building.

Because the BPRG models will tend to over-estimate dose in the dust settling model and may under estimate dose in the external model it is a useful tool to develop initial screening criteria and to provide some idea of the upper and lower ranges of DCGLs, which can be compared to DCGLs derived from RESRAD-Build.

To compare the two models the parameters for RESBLD were adjusted to reflect the inputs of the BPRG calculator and the site as close as possible. A 50’ x 50’ x 10’ room was modeled with a receptor located in the center of the room and breathing rates and dissipation rates were matched between the two models. Note that this is larger than the 100 square meter of floor area recommended in the Multi-Agency Radiation Survey and Site Investigation Manual (EPA 2000).

Tables 2 and 3 show comparisons of the RESBLD residential DCGL values compared to default and site specific PRGs derived from the BPRG calculator. In order to match the site specifics, the BPRG calculator model included adjustments for exposure time, room size, and dissipation rate, which made a small difference in DCGL values between the default and site specific case.

Table 2. Residential Default Case ($1x10^{-4}$ risk) ($dpm/100cm^2$)

Radionuclide	BPRG Settled Dust	BPRG 3-D Direct External Exposure	RESRAD-Build
Thorium 232	71	924,000	
Radium 228+D	26	879	
Thorium 228	617	1,980,000	
Radium 224+D	1,230,000	977,000	
Total thorium	**18**	**877**	**307**
Radium 226+D	**22**	**355**	**884**

Table 3. Residential Site Specific Case ($1x10^{-4}$ risk) ($dpm/100cm^2$)

Radionuclide	BPRG Settled Dust	BPRG 3-D Direct External Exposure	RESRAD-Build
Thorium 232	90	1,784,880	
Radium 228+D	33	1,334	
Thorium 228	781	3,596,400	
Radium 224+D	1,560,660	1,374,180	
Total thorium	**23**	**1,331**	**307**
Radium 226+D	**28**	**526**	**884**

From the comparison we can see that for thorium contamination the RESBLD derived DCGL of 307 dpm/100 cm^2 falls between the two site specific model values of 23 dpm/100 cm^2 and 1,331 dpm/100 cm^2. This suggests that the models are in good agreement based on the fact that analysis of the RESBLD generated risk assessment shows that the risk to a receptor comes approximately 50% from external radiation and 50% inhalation.

A comparison of the radium 226+D DCGL value of 884 dpm/100 cm^2 derived from RESBLD to the external exposure PRG of 526 dpm/100 cm^2 from the site specific BPRG model also shows that the two models are in agreement when model uncertainty is considered. It was noted during the evaluation that while both the BPRG model and RESBLD cite FGR 13 and HEAST 2001 as the sources of their slope conversion factors for risk assessment, the User's Guide for the Online BPRG Calculator notes that the ground plane slope factor used was *developed* specifically for the BPRG from values from FGR 13. As such it's likely that the two models handle risk coefficients slightly differently and can be expected to give slightly different values.

Additionally, the BPRG calculator models external exposure as a result of contamination present in an infinite plane. Though the model corrects for this using a surface factor this is another area where the models differ and could be expected to produce results that differ slightly.

Ultimately, both models arrive at similar values at the desired risk range. The fact that the BPRG derived PRGs and the RESBLD DCGLs compare well is not surprising, as much of the calculations and framework of the two models come from the same source. Again citing the online User's Manual for the BPRG calculator –

> *"Calculation of the recommended BPRGs are based on the risk assessment work EPA 2003 for chemicals and RESRAD BUILD (Developed for The U.S. Department of Energy by Argonne National Laboratory) and the default inputs are based on Superfund parameters."*

4. DCGL Discussions

4.1 The comparisons in paragraph 3 above were conducted to best compare the two models. The RESBLD model was changed slightly from that used in the BRA and FS to better match the BPRG model for comparison purposes. As such the DCGLs presented in Tables 1 and 2 will likely not match those in the final FS.

4.2 The comparison used a fixed $1x10^{-4}$ risk as the upper bound of the acceptable risk range. As discussed in EPA OSWER Directive 9200.4-18 (EPA 1997) the risk range is not a hard line and especially when meeting dose based ARARs exceeding $1x10^{-4}$ risk may be acceptable.

4.3 The OSWER 9200.4-18 (EPA 1997) also states that 15 mrem/yr roughly equates to 3.4×10^{-4} risk, and considers this acceptable.

4.4 The Welsbach/GGM Superfund Site is in New Jersey. New Jersey has a promulgated standard (NJAC 7:28-12, NJDEP 2000) for protection from residual radiation exposure of 15 mrem/yr. Accordingly, there is a potential that this standard may become an ARAR for the Armstrong Building Operable Unit.

4.5 Modifying the acceptable risk to $3x10^{-4}$ effectively would triple the DCGLs presented in Tables 2 and 3 above. Table 4 presents site specific DCGLs based on $3x10^{-4}$ risk.

4.6 Table 5 presents a range of acceptable DCGLs for the Armstrong Building given the different models and site specific inputs.

Table 4. Residential Site Specific Case (3x10^{-4} risk) (dpm/100cm^2)

Radionuclide	[1]Settled Dust	3-D Direct External Exposure	RESRAD-Build
Thorium 232	270	5,354,640	
Radium 228+D	99	4,002	
Thorium 228	2343	10,789,200	
Radium 224+D	4,681,980	4,122,540	
Total thorium	**69**	**3,993**	**921**
Radium 226+D	**84**	**1,578**	**2,652**

[1] Eliminated from consideration due to future use scenario limitations, see paragraph 3.2.1.

Table 5. DCGL Range (dpm/100cm^2)

Radionuclide	BPRG Range	RESBLD Range	Combined Range
Th-232 (chain)	1,331 – 3,993	307 - 921	307 – 3,993
Ra-226+D	526 - 1,578	884 – 2,652	526 – 2,652

5. Uncertainty

5.1 It should be noted that significant uncertainty is inherent in any modeling and most are not discussed here. Ultimately the BRA and the FS will address DCGL model uncertainty.

5.2 USACE compared the BPRG calculator external exposure model DCGL results for the Th-232 and Ra-226 decay chains versus hand calculations and calculating the decay chain DCGL by individual radionuclide versus using the +D radionuclide inputs.

5.2.1 Hand calculations verified the BPRG calculator worked as designed. In some instances, significant figures truncating or rounding add some level of uncertainty between hand calculations and the BPRG calculated and reported results. This difference is unlikely to be significant but should be understood when developing DCGLs.

5.2.2 In theory, using an individual decay chain radionuclide approach and a radionuclide+D approach should result in similar DCGLs. For the Ra-226 decay chain and the Th-232 decay chain significant differences in the resulting DCGLS were observed between the individual and +D approaches. This may be due to several factors which are not fully understood by USACE at this time. Significant uncertainty appears to exist in the use of BPRG calculator for future use scenarios and complex decay chain calculations especially the Th-232 decay chain.

6. Conclusions

6.1 The RESRAD-Build Model and BPRG calculator compare favorably. The ability for RESRAD-BLD to better model future use scenarios and to be more site specific is an advantage to the Armstrong Building project team due to the amount of site specific data available from the Remedial Investigation (RI) and the recent supplemental RI.

6.2 The online BPRG calculator serves as a useful tool for a first estimate of screening levels at the Armstrong building. The incorporation of site specific data into the BPRG calculator and then into RESRAD-Build has facilitated the evolution of initial generalized BPRG derived values into more accurate and site specific DCGLs ranges.

6.3. A better understanding of the BPRG calculator and how it handles complex decay chain calculation for future use scenarios is required before USACE can recommend use of the BPRG calculator to develop DCGLS for the Th-232 decay chain.

7. Recommendations

7.1 **Use** of the RESRAD-BLD code to develop DCGLs for the Armstrong Building at the Welsbach/GGM Superfund site is recommended due to the amount of available site specific data and the flexibility of the model.

7.2 Developed DCGLS should be within the ranges of DCGLs presented in Table 5.

8. References

DOE 2009 *RESRAD-Build User Manual*, Environmental Assessment Division, Argonne National Laboratory. Argonne, Illinois. ANL/EAD/03-1. June. Model Updated 2009.

EPA 2009 *Preliminary Remediation Goals for Radionuclides in Buildings* (BPRG) User's Guide Last updated on Tuesday, July 8th, 2008. Model update 2009.

EPA 2000 *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM), Revision 1. EPA, August 2000.

EPA 1997 OSWER 9200.4-18, *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*, EPA, OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE, August 20, 1997.

NJDEP 2000 *New Jersey Administrative Code* (NJAC 7:28-12). Radiation Protection Programs, Subchapter 12, Remediation Standards for Radioactive Materials, August.

Attachment 1

Summary Tables from BPRG Calculator

Site-specific	
Resident Equation Inputs for Settled Dust	
Variable	**Value**
TR (target cancer risk) unitless	0.0001
t_r (time - resident) yr	30
F_{in} (fraction time spent indoors) unitless	0.875
k (dissipation rate constant) yr^{-1}	0.01
EF_r (exposure frequency) day/yr	365
F_{AM} (area and material factor) unitless	1
ET_r (exposure time) hr/day	24
$F_{OFF-SET}$ (off-set factor) unitless	1
F_i (fraction of time spent in compartment) unitless	1
$FTSS_h$ (fraction transferred surface to skin - hard surface) unitless	0.5
SE (saliva extraction factor) unitless	0.5
IFD_{r-adj} (age-adjusted dust ingestion rate - resident) cm^2/day	3870
ED_r (exposure duration - resident) yr	30
ED_{r-a} (exposure duration - resident adult) yr	24
ED_{r-c} (exposure duration - resident child) yr	6
$ET_{r-c,h}$ (exposure time - resident child hard surface) hr/day	6
$ET_{r-a,h}$ (exposure time - resident adult hard surface) hr/day	6
$ET_{r-c,s}$ (exposure time - resident child soft surface) hr/day	10
$ET_{r-a,s}$ (exposure time - resident adult soft surface) hr/day	10
FQ_a (frequency of hand to mouth - adult) event /hr	1
FQ_c (frequency of hand to mouth - child) event/hr	9.5
SA_{r-a} (surface area of fingers - resident adult) cm^2	45
Output generated 31MAY2011:13:51:09	

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Site-specific				
Resident Building Preliminary Remediation Goals for Settled Dust				
Radionuclide	**Soil Ingestion Slope Factor (risk/pCi)**	**Ground Plane External Exposure Slope Factor (risk/yr per pCi/cm^2)**	**Lambda**	**BPRG (pCi/cm^2)**
Ra-224+D	-	1.30E-06	6.91E+01	7.03E+03
Ra-226+D	7.30E-10	1.54E-06	4.33E-04	1.24E-01
Ra-228+D	2.29E-09	2.16E-06	1.21E-01	1.49E-01
Th-228	2.89E-10	1.87E-09	3.62E-01	3.52E+00
Th-232	2.31E-10	3.20E-10	4.93E-11	4.05E-01
Output generated 31MAY2011:13:51:09				

Site-specific	
Resident Equation Inputs for 3-D Direct External Exposure	
Variable	**Value**
Room size & position	50 x 50 x 10 - Average
TR (target cancer risk) unitless	0.0001
F_i (fraction of time spent in compartment) unitless	0.875
$F_{OFF-SET}$ (off-set factor) unitless	1
ED_r (exposure duration - resident) yr	30
ET_r (exposure time - resident) hr/day	24
t_r (time - resident) yr	30
F_{in} (fraction time spent indoors) unitless	1
F_{am} (area and materials factor) unitless	1
EF_r (exposure frequency) day/yr	365
GSF (gamma shielding factor) unitless	1
Output generated 31MAY2011:13:51:09	

Site-specific				
Resident Building Preliminary Remediation Goals for 3-D Direct External Exposure				
Radionuclide	**Ground Plane External Exposure Slope Factor (risk/yr per pCi/cm^2)**	**F_{SURF}**	**Lambda**	**Ground Plane BPRG (pCi/cm^2)**
Ra-224+D	1.30E-06	0.981	6.91E+01	6.19E+03
Ra-226+D	1.54E-06	1.05	4.33E-04	2.37E+00
Ra-228+D	2.16E-06	1.09	1.21E-01	6.01E+00
Th-228	1.87E-09	1.37	3.62E-01	1.62E+04
Th-232	3.20E-10	1.48	4.93E-11	8.04E+03
Output generated 31MAY2011:13:51:09				

Attachment 2

Th-232 Decay Chain

Summary Tables from BPRG Calculator VS Hand Calculation

And

Individual DCGL vs +D Comparison

Model Inputs for Check of Individual Calcs

BPRG Calculator	50x50x10 room average receptor location
Variable	**Value**
Room size & position	50 x 50 x 10 - Average
TR (target cancer risk) unitless	1.00E-06
F_i (fraction of time spent in compartment) unitless	1
$F_{OFF\text{-}SET}$ (off-set factor) unitless	1
ED_r (exposure duration - resident) yr	30
ET_r (exposure time - resident) hr/day	24
t_r (time - resident) yr	30
F_{in} (fraction time spent indoors) unitless	0.875
F_{am} (area and materials factor) unitless	1
EF_r (exposure frequency) day/yr	350
GSF (gamma shielding factor) unitless	1

Ground Plane BPRG (pCi/cm^2)	Radionuclide	External Exposure Slope Factor (risk/yr per pCi/g)	Ground Plane External Exposure Slope Factor (risk/yr per pCi/cm^2)	External Exposure Slope Factor (1 cm) (risk/yr per pCi/g)	External Exposure Slope Factor (5 cm) (risk/yr per pCi/g)	External Exposure Slope Factor (15 cm) (risk/yr per pCi/g)	F_{SURF}	Lambda	Soil Volume BPRG (pCi/g)	Ground Plane BPRG (pCi/cm^2)	Soil Volume BPRG (1 cm) (pCi/g)
1.09E+03	Ac-228	4.53E-06	8.56E-07	5.48E-10	2.49E-06	3.92E-06	1.26	9.90E+02	2.07E+02	1.09E+03	1.71E+06
2.97E+04	Bi-212	8.88E-07	1.71E-07	1.06E-10	4.82E-07	7.64E-07	1.41	6.02E+03	5.73E+03	2.97E+04	4.80E+07
5.40E+03	Pb-212	5.09E-07	1.26E-07	7.95E-11	3.46E-07	4.89E-07	0.999	5.71E+02	1.34E+03	5.40E+03	8.56E+06
-	Po-212	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	7.17E+13	-	-	-
1.30E+13	Po-216	7.87E-11	1.52E-11	9.73E-15	4.40E-11	6.90E-11	0.88	1.46E+08	2.51E+12	1.30E+13	2.03E+16
9.77E+03	Ra-224	3.73E-08	8.58E-09	5.50E-12	2.46E-08	3.56E-08	0.983	6.91E+01	2.25E+03	9.77E+03	1.52E+07
6.46E+01	Ra-224+D	7.77E-06	1.30E-06	8.42E-10	3.90E-06	6.33E-06	0.981	6.91E+01	1.08E+01	6.46E+01	9.97E+04
-	Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	1.21E-01	-	-	-
6.27E-02	Ra-228+D	1.23E-05	2.16E-06	1.39E-09	6.39E-06	1.03E-05	1.09	1.21E-01	1.10E-02	6.27E-02	9.74E+01
1.69E+02	Th-228	5.59E-09	1.87E-09	1.03E-12	4.17E-09	5.49E-09	1.37	3.62E-01	5.64E+01	1.69E+02	3.06E+05
8.39E+01	Th-232	3.42E-10	3.20E-10	8.65E-14	2.87E-10	3.40E-10	1.48	4.93E-11	7.85E+01	8.39E+01	3.10E+05
5.63E+04	Tl-208	1.76E-05	2.77E-06	1.81E-09	8.48E-06	1.40E-05	0.907	1.19E+05	8.86E+03	5.63E+04	8.61E+07
1.49E+09	Rn-220	1.71E-09	3.47E-10	2.22E-13	1.00E-09	1.54E-09	0.906	3.93E+05	3.02E+08	1.49E+09	2.33E+12

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Check of BPRG External Equation

Radionuclide	Lambda	Ground Plane External Exposure Slope Factor (risk/yr per pCi/cm^2)	F_{SURF}	Hand Calc BPRG (pCi/cm^2)	Check Hand - BPRG difference (Rounding)
Ac-228	9.90E+02	8.56E-07	1.26	1.09E+03	3.98E+00
Bi-212	6.02E+03	1.71E-07	1.41	2.98E+04	5.76E+01
Pb-212	5.71E+02	1.26E-07	0.999	5.41E+03	6.51E+00
Po-216	1.46E+08	1.52E-11	0.88	1.30E+13	8.98E+09
Ra-224	6.91E+01	8.58E-09	0.983	9.76E+03	-5.41E+00
Th-228	3.62E-01	1.87E-09	1.37	1.68E+02	-5.89E-01
Th-232	4.93E-11	3.20E-10	1.48	8.39E+01	-1.51E-02
Tl-208	1.19E+05	2.77E-06	0.907	5.65E+04	1.52E+02
Rn-220	3.93E+05	3.47E-10	0.906	1.49E+09	-1.19E+05

MARSSIM equation 4-4 Combined PRG Calculation

Radionuclide	Ground Plane BPRG (pCi/cm^2)	Fraction of (COC) activity in chain	Fraction/PRG	1/(sum of fraction/PRG) Combined PRG
Ac-228	1.09E+03	0.119617	1.10E-04	
Bi-212	2.97E+04	0.119617	4.03E-06	
Pb-212	5.40E+03	0.119617	2.22E-05	
Po-216	1.30E+13	0.119617	9.20E-15	
Ra-224	9.77E+03	0.119617	1.22E-05	
Th-228	1.69E+02	0.119617	7.08E-04	
Th-232	8.39E+01	0.119617	1.43E-03	
Tl-208	5.63E+04	0.043062	7.65E-07	
Rn-220	1.49E+09	0.119617	8.03E-11	
		sum of Frac check		(pCi/cm2)
		1.000000		**4.38E+02**
		dpm/100cm2=		9.73E+04
		1x10-4 PRG		9.73E+06

Th-232+D
(pCi/cm2)
5.24E+01
1.16E+04
1.16E+06

Ground Plane BPRG (pCi/cm^2)	Radionuclide	External Exposure Slope Factor (risk/yr per pCi/g)	Ground Plane External Exposure Slope Factor (risk/yr per pCi/cm^2)	External Exposure Slope Factor (1 cm) (risk/yr per pCi/g)	External Exposure Slope Factor (5 cm) (risk/yr per pCi/g)	External Exposure Slope Factor (15 cm) (risk/yr per pCi/g)	F_{SURF}	Lambda	Soil Volume BPRG (pCi/g)	Ground Plane BPRG (pCi/cm^2)	Soil Volume BPRG (1 cm) (pCi/g)
1.09E+03	Ac-228	4.53E-06	8.56E-07	5.48E-10	2.49E-06	3.92E-06	1.26	9.90E+02	2.07E+02	1.09E+03	1.71E+06
2.97E+04	Bi-212	8.88E-07	1.71E-07	1.06E-10	4.82E-07	7.64E-07	1.41	6.02E+03	5.73E+03	2.97E+04	4.80E+07
5.40E+03	Pb-212	5.09E-07	1.26E-07	7.95E-11	3.46E-07	4.89E-07	0.999	5.71E+02	1.34E+03	5.40E+03	8.56E+06
-	Po-212	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	7.17E+13	-	-	-
1.30E+13	Po-216	7.87E-11	1.52E-11	9.73E-15	4.40E-11	6.90E-11	0.88	1.46E+08	2.51E+12	1.30E+13	2.03E+16
9.77E+03	Ra-224	3.73E-08	8.58E-09	5.50E-12	2.46E-08	3.56E-08	0.983	6.91E+01	2.25E+03	9.77E+03	1.52E+07
6.46E+01	Ra-224+D	7.77E-06	1.30E-06	8.42E-10	3.90E-06	6.33E-06	0.981	6.91E+01	1.08E+01	6.46E+01	9.97E+04
-	Ra-228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	1.21E-01	-	-	-
6.27E-02	Ra-228+D	1.23E-05	2.16E-06	1.39E-09	6.39E-06	1.03E-05	1.09	1.21E-01	1.10E-02	6.27E-02	9.74E+01
1.69E+02	Th-228	5.59E-09	1.87E-09	1.03E-12	4.17E-09	5.49E-09	1.37	3.62E-01	5.64E+01	1.69E+02	3.06E+05
8.39E+01	Th-232	3.42E-10	3.20E-10	8.65E-14	2.87E-10	3.40E-10	1.48	4.93E-11	7.85E+01	8.39E+01	3.10E+05
5.63E+04	Tl-208	1.76E-05	2.77E-06	1.81E-09	8.48E-06	1.40E-05	0.907	1.19E+05	8.86E+03	5.63E+04	8.61E+07
1.49E+09	Rn-220	1.71E-09	3.47E-10	2.22E-13	1.00E-09	1.54E-09	0.906	3.93E+05	3.02E+08	1.49E+09	2.33E+12

Check of BPRG External Equation

Radionuclide	Lambda	Ground Plane External Exposure Slope Factor (risk/yr per pCi/cm^2)	F_{SURF}	Hand Calc BPRG (pCi/cm^2)	Check Hand - BPRG difference
Th-232	4.93E-11	3.20E-10	1.48	8.39E+01	-1.51E-02
Ra-228+D	1.21E-01	2.16E-06	1.09	6.29E-02	2.21E-04
Th-228	3.62E-01	1.87E-09	1.37	1.68E+02	-5.89E-01
Ra-224+D	6.91E+01	1.30E-06	0.981	6.46E+01	-2.23E-02

MARSSIM equation 4-4 Combined PRG Calculation

Radionuclide	Ground Plane BPRG (pCi/cm^2)	Fraction of (COC) activity in chain	Fraction/PRG	1/(sum of fraction/PRG) Combined PRG
Th-232	8.39E+01	0.1196172	1.43E-03	
Ra-228+D	6.29E-02	0.1196172	1.90E+00	
Th-228	1.68E+02	0.1196172	7.10E-04	
Ra-224+D	6.46E+01	0.6411483	9.93E-03	
		sum of Frac check 1.000000		(pCi/cm2) **5.23E-01**

Ra-224+D External SF in BPRG is = to Th-228+D external SF from Heast

BPRG manual states to use Th-228+D but it is not a choice in BPRG

BPRG ground plane SF and Fsurf are different between Ra-224+D and Th-228

dpm/100cm2=	1.16E+02
1x10-4 PRG	1.16E+04

Should be noted that the theoritical ground plane SF for Th-232+D equals Ra-228+D GPSF

When Th232+D calc done in cell L39 result is basically same as Ra-228+D.

The Th-232+D PRG is very close to that from Ra-228+D.

Th232 (mod for D)	6.25E-02
dpm/100cm2=	1.39E+01
1x10-4 PRG	1.39E+03